Hydrodesulphurization of Light Gas Oil using Hydrogen from the Water Gas Shift Reaction

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

The production of clean fuel faces the challenges of high production cost and complying with stricter environmental regulations. In this research, the ability of using a novel technology of upgrading heavy oil to treat Light Gas Oil (LGO) will be investigated. The target of this project is to produce cleaner transportation fuel with much lower cost of production.

Recently, a novel process for upgrading of heavy oil has been developed at University of Waterloo. It is combining the two essential processes in bitumen upgrading; emulsion breaking and hydroprocessing into one process. The water in the emulsion is used to generate in situ hydrogen from the Water Gas Shift Reaction (WGSR). This hydrogen can be used for the hydrogenation and hydrotreating reaction which includes sulfur removal instead of the expensive molecular hydrogen. This process can be carried out for the upgrading of the bitumen emulsion which would improve its quality.

In this study, the hydrodesulphurization (HDS) of LGO was conducted using in situ hydrogen produced via the Water Gas Shift Reaction (WGSR). The main objective of this experimental study is to evaluate the possibility of producing clean LGO over dispersed molybdenum sulphide catalyst and to evaluate the effect of different promoters and syn-gas on the activity of the dispersed Mo catalyst.

Experiments were carried out in a 300 ml Autoclave batch reactor under 600 psi (initially) at 391^{o}C for 1 to 3 hours and different amounts of water. After the hydrotreating reaction, the gas samples were collected and the conversion of carbon monoxide to hydrogen via WGSR was determined using a refinery gas analyzer. The sulphur content in liquid sample was analyzed via X-Ray Fluorescence.

Experimental results showed that using more water will enhance WGSR but at the same time inhibits the HDS reaction. It was also shown that the amount of sulfur removed depends on the reaction time. The plan is to investigate the effect of synthesis gas (syngas) molar ratio by varying CO to H_2 ratio. It is also planned to

use different catalysts promoters and compare them with the un-promoted Mo based catalysts to achieve the optimum reaction conditions for treating LGO.

The results of this study showed that Ni and Co have a promoting effect over un-promoted Mo catalysts for both HDS and WGSR. Ni was found to be the best promoter for both reactions. Fe showed no significant effect for both WGSR and HDS. V and K have a good promoting effect in WGSR but they inhibited the HDS reaction. Potassium was found to be the strongest inhibitor for the HDS reaction since no sulfur was removed during the reaction

Keywords: LGO, HDS, in situ H_2, WGSR, oil upgrading, syn-gas.

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Chapter 1
Introduction

1.1 Background

Producing clean transportation fuel at lower cost has become a major challenge for refiners around the world. This is mainly due to the decline of crude quality, high demand, and stricter environmental regulations. Hydrodesulphurization (HDS) is a major process in producing clean fuel. Many diesel hydrotreating plants have been commissioned recently in order to meet the high demand and also to meet the environmental regulations by producing ultra-clean diesel fuel.

There is a vast amount of sand oil located in Alberta, Canada. Due to the poor quality of this oil, it is not feasible to economically recover and process it using conventional methods. Table 1.1.1 shows the properties of the Cold Lake crude oil, as stated by Environment Canada on March 28, 2009. Currently, the heavy oil upgrading process includes the injection of water or steam during the extraction process. The injection of steam and hot water results in mixing water with the sand oil and forming an emulsion. The resulting emulsion must be broken and dewatered in order to protect the catalysts in the next process. After dewatering, the resulting crude oil is hydrotreated using molecular hydrogen in the presence of a catalyst to reduce or eliminate the undesirable materials and to improve the physical properties of the oil.

A novel process was developed and patented in the early 1990s by Professor Flora Ng's group to upgrade the heavy oil emulsion using the in-situ hydrogen generated by the Water Gas Shift Reaction (WGSR) for the HDS. This process combined the two separate processes into one single process in which the water associated with the bitumen emulsion was utilized for the in-situ generation of the hydrogen needed in the HDS.

Table 1.1.1: Cold Lake Crude properties (Environment Canada)

API Gravity	9.8-13.2
Sulphur (weight %)	4.11-6.9
Flash Point (°C)	81
Density (g/mL) at 25 °C	0.9943
Dynamic Viscosity (mPa·s or cP) 15 °C	235000
Asphaltenes (weight %)	13
Cobalt (ppm)	<1
Iron (ppm)	15.2
Molybdenum (ppm)	3.7
Nickel (ppm)	69
Vanadium (ppm)	190
Nitrogen (weight %)	0.42
Boiling Point Distribution (weight %)	
(°C)	
200	1
250	3
300	8
350	15
400	22
450	29
500	37
550	45
600	54
650	62
700	69

Many experiments have been conducted using sulfur-containing and nitrogen-containing compounds. This study was done using real bitumen-derived LGO as a good model for the bitumen-upgrading process. The experimental study focused on the major factors that affect the HDS and WGSR.

A preliminary investigation was reported by Siewe and Ng (1998) on HDS of a Cold Lake (Alberta) diesel fraction using dispersed catalysts. The main objective of their study was to examine the performance of a molybdenum-based, dispersed catalyst in different media and with different sources of hydrogen. The study was performed in an autoclave batch reactor at 340^{o}C, using ammonium tetrathiomolybdate (ATTM) and phosphomolybdic acid (PMA) as dispersed catalysts. There were two main sources of hydrogen, i.e., an external supply of molecular hydrogen and in-situ hydrogen generated from the water-gas shift reaction (WGSR). The major conclusion of this study was that Mo-based, dispersed catalysts and flue gases can be used to reduce the sulfur content in diesel fuel to a satisfactory level.

1.2 Objectives

The main objective of this project is to investigate the effect of different factors on the treatment of the LGO as a model for the bitumen-upgrading process. The HDS of LGO using different gas media was studied using molecular hydrogen and in-situ hydrogen produced by the WGSR and also different compositions of syn-gas. Also, in addition to a dispersed molybdenum sulfide-based catalyst, the effect of different promoters on WGSR and HDS was also investigated.

The main goals of this study were:

I. To determine the effect of different promoters on the treatment of LGO, especially the metals that are associated with bitumen, such as Fe, V, Co, K, and Ni.

II. To determine the effect of syn-gas composition on HDS and the WGSR.

III. To determine the effects of other reaction parameters, such as temperature, time, and water content on both WGSR and HDS.

Chapter 2

Literature Review

2.1 Dispersed Catalysts for Upgrading Heavy Oil

Many experimental studies have been conducted to compare dispersed catalysts and supported catalysts. Dispersed catalysts have been found to be more suitable than supported catalysts for heavy oil processing. Because of the nature of heavy oil, catalysts tend to be deactivated very rapidly due to pore plugging and coke formation. Due to mass transfer limitations, supported catalysts are not suitable for processing large asphaltene molecules. Also, the pores of the catalyst could be plugged, and the metal compounds associated with the heavy oil could poison the catalyst. The use of unsupported, dispersed catalysts can be an alternative. In 1998, Tian et al. compared Co-Mo supported catalysts with dispersed catalysts and showed that the dispersed catalysts were more selective and produced higher conversion efficiency for the catalytic upgrading of petroleum residue oil. It is believed that the small size of dispersed catalysts helps in rapid diffusion through the asphaltene particles.

Highly-dispersed, Mo sulfide catalysts were studied by Bearden (1981). Bearden used vacuum residue as feed and managed to convert up to 95% of the residue to naphtha, distillate, and gas oil. Bearden claimed that there will be no feed quality limitations when such highly-dispersed catalysts are used for upgrading heavy oil. Thompson (2008) studied the synthesis of ultra-dispersed, molybdenum-based catalysts from water-in-oil emulsions. The study showed that the particle size increases with increasing decomposition temperature.

Ovalles et al. (2003) used an iron dispersed catalyst for upgrading extra-heavy crude oil, using methane the source of hydrogen in a batch reactor. Ovalles et al. achieved a 14% reduction in sulfur content and 41% conversion of the >500 °C fraction. Four different metals were tested by Shi and Li (1998) as active sites of dispersed catalysts for upgrading heavy oil. The catalytic activities of the dispersed metals were found to be in order of Mo>Co>Ni>Fe. The addition of phosphoric acid to phosphomolybdic acid

(PMA) was found to be more effective (Bearden, 1981). There have been many other studies that showed promising results using highly dispersed catalysts for upgrading heavy oil (Farshid, 2007; Ho, 2008; Liu, 1999; Liu, 2005; Panariti, 2002; Rispoli, 2008; Thompson, 2008; Tye, 2004; Cheng, 2008).

There are many advantages of dispersed catalysts over the supported catalysts, including the ability of the catalysts to be dispersed into the reaction medium, the larger surface area of the active sites, the resistance to the formation of coke, the ability of large reactant molecules to reach the active sites, and the recyclability of the used catalyst (Siewe and Ng, 1998; Fixari et al., 1994; Del Bianco et al., 1993). Therefore, dispersed catalysts are more desirable for treating heavy oil than supported catalysts.

2.2 Water-gas shift reaction

The water-gas shift reaction (WGSR) is a catalytic reaction between carbon monoxide and water (or steam) to produce hydrogen and carbon dioxide. This reaction was used in the 1980s to improve coal gasification. It has also been used to produce high purity hydrogen from ammonia synthesis, Fischer-Tropsch synthesis, steam reforming and hydrotreating processes (Twigg, 1989; Rintjema, 1992).

The water-gas shift reaction is an exothermic reaction when steam is used and an endothermic reaction when water is used, as shown in equations 2.2.1 and 2.2.2 (McQuarrie and Rock, 1984);

$$CO_{(g)} + H_2O_{(g)} \leftrightarrows CO_{2(g)} + H_{2(g)} \qquad (2.2.1)$$

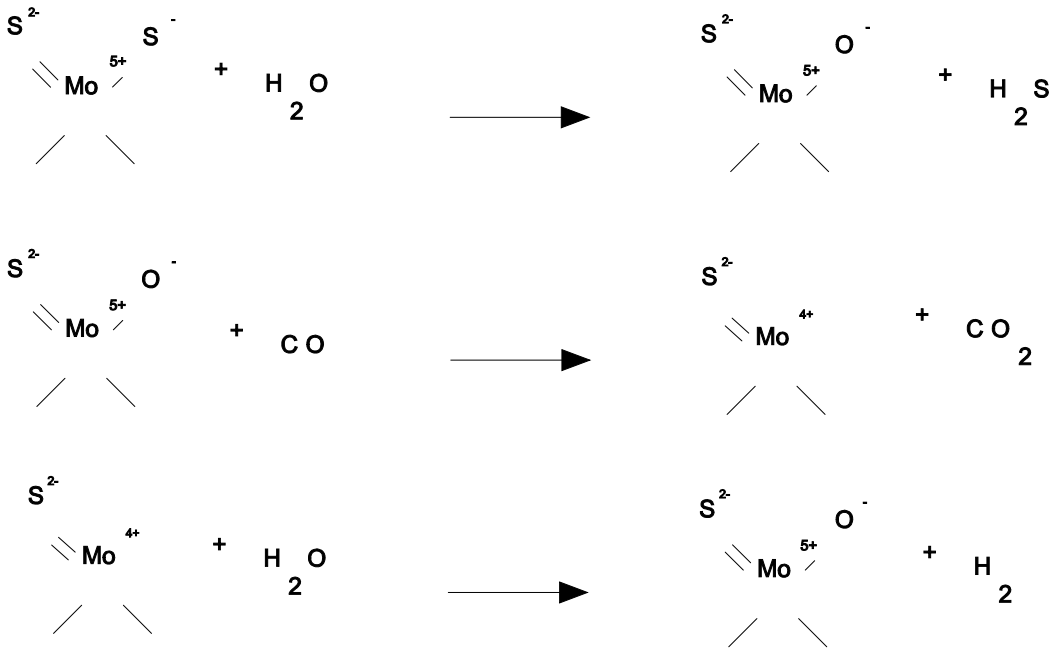
ΔS^o = -42.3 kJ/mol•K, ΔH^o = -41.1 kJ/mol, Δ^oG = -28.7 kJ/mol

$$CO_{(g)} + H_2O_{(l)} \leftrightarrows CO_{2(g)} + H_{2(g)} \qquad (2.2.2)$$

ΔS^o = +76.6 kJ/mol•K, ΔH^o = +2.8 kJ/mol, Δ^oG = -20.1 kJ/mol

The commonly used catalysts for WGSR when sulfur exists in the feedstock are MoS_2 and $NiMoS_2$. Molybdenum oxide is used as a precursor where sulfur in the feed could be used to sulfide the catalysts. Therefore, molybdenum oxide is used in cases in which the presence of sulfur enhances the ability of the catalysts to catalyze the WGSR (Hou, 1983; Twigg, 1989).

The following mechanism for the WGSR using MoS catalysts in the presence of H_2S was suggested by Hou et al., (1983);



It was also suggested that the WGSR can be autocatalyzed by H_2S via the following equations (Rintjema, 1992; Adschiri, et al., 1998).

$$H_2S + CO \leftrightarrows COS + H_2$$

$$COS + H_2O \leftrightarrows CO_2 + H_2S$$

Hence, it is important to determine the optimum proportion of H_2O, H_2S, CO, and H_2 to achieve the maximum WGSR activity over an MoO_x catalyst.

The water-gas shift reaction can be also utilized in the bitumen emulsion-upgrading process. The water associated with the emulsion can be used to produce in-situ hydrogen instead of dewatering the emulsion and then using expensive molecular hydrogen for the hydrotreating processes. Therefore, substituting in-situ hydrogen for the molecular hydrogen and substituting synthesis gas (syn-gas) for carbon monoxide are cost-effective changes in the process. Syn-gas can be produced by gasifying the asphaltene that is recovered from the upgrading process (Ng and Tsakiri, 1989; Hook and Akgerman, 1986).

Lee and Ng (2006) correlated the relationship between the reactivity of the hydrogen source and the amount of water used in the WGSR. They achieved higher HDS activity in the in-situ H_2 run compared to molecular hydrogen at an optimized mole ratio of H_2O:CO of 1.35. In another study, Ng found that synthesis gas was more effective than molecular hydrogen for upgrading emulsions (Ng, 1998).

The activity of in-situ hydrogen has been found to be equivalent to or greater than the activity of molecular hydrogen in many studies (Lee, 2006; AbuSaido, 1999; Zhang, 2005; Adschiri, 1998); Ng and Rintjema, 1992). Moll (1999) found that in-situ hydrogen is more active and produces higher quality product (lower boiling point range) from the upgrading of the Cold Lake bitumen emulsion (Moll, 1999). It was found also that water inhibits the HDS reaction (Moll, 1999; Takemura, 1981; Clark and Kirk, 1994). Another study was carried out by Siewe and Ng using diesel cut derived from Cold Lake bitumen in which it was found that in-situ hydrogen was comparable to molecular hydrogen (Siewe, 1998).

Cheng et al. (2008) studied the hydrocracking of Gudao residue using in-situ hydrogen generated from the WGSR for the hydrocracking process and supercritical water. They were able to convert more than 80% of the CO. It was found that the WGSR could be effectively enhanced by using dispersed catalysts.

2.3 Hydrotreating

The hydrotreating process is a catalytic process used to remove undesirable materials, such as aromatics, sulfur- and nitrogen-containing compounds, and metals, from oil. This process usually takes place at high temperature and moderate pressure in the presence of catalysts and hydrogen. Hydrotreating is used around the world for upgrading heavy oil.

Due to stricter environmental regulations, the declining quality of crude oil, and varying market demand, hydroprocessing has become more important in the refining industry. In a refinery, the products from the hydrotreating process have lower concentrations of sulfur, nitrogen, aromatic compounds, and other contaminants. In addition, they also have improved stability. For upgrading oil, hydrotreating has the advantage over other processes when it comes to the quality of the product (Marafi, 2005). The objectives of hydrotreating are mainly to remove impurities, such as S, aromatic compounds, and metals, increase the hydrogen content, and lower the boiling point range of the feedstock being processed.

Most hydrotreating processes use Mo- and W-based sulfides supported on alumina with promoters of Ni or Co sulfide catalysts. In terms of surface area, pore size control, affinity for sulfide for high dispersion, mechanical strength, and cost, gamma alumina is believed to be the best support. The active species of a hydrotreating catalyst, Co(Ni)MoS, consists of small layered crystals of S and Co/Mo on the alumina support (Whitehurst, 1998).

The hydrotreating catalyst is mainly deactivated either by coke formation or metal deposits (Marafi et al., 2005). In this report, deactivation due to metal deposits was studied in terms of mechanism and profile and the recent studies that have been done to determine the effect of metals on hydrotreating so that a method can be devised to reduce this effect.

Usually, deactivation occurs in three steps i.e., initial rapid deactivation, intermediate slow, but steady, deactivation, and rapid deactivation at the end of the cycle. To compensate for the deactivation of the catalyst, commercial processes are operated using a gradual increase in temperature in order to achieve constant conversion during the cycle length of the catalysts (Mochida, 2006).

Due to the restrictions of environmental regulations, ultra-low-sulfur diesel fuel and gasoline have been targeted for quality improvements for use in the transportation fuel sector. This trend is expected to continue until the sulfur concentration is reduced to parts per billion based on wt% (wppb). Hence, to meet the requirements of this low-sulfur-emission legislation, high efficiency hydrotreating technology is required. It will be more challenging in the future, especially for upgrading the heavy oil and residue as the demand increases and crude oil with higher sulfur content will have to be processed.

In a conventional hydrotreater, a significant fraction of the sulfur species in the diesel fuel is removed. For ultra-deep desulfurization, liquid products from this process may be fed to a second hydrotreater to remove residual refractory sulfur species (Ho and Markley, 2004).

The main bottleneck related to the desulfurization of gasoline is the issue of removing sulfur from Fluid Catalytic Cracking (FCC) naphtha, which contributes about 35% of the gasoline demand but contributes more than 90% of sulfur emitted from the combustion of gasoline. Deep desulfurization of gasoline (from 330 ppm to 30 ppm of sulfur) can be achieved without decreasing the octane number or reducing the gasoline yield. The high olefinic content of FCC naphtha, which contributes to octane number enhancement, makes it more challenging.

For diesel fuel, deep reduction of sulfur (from 500 ppm to <15 ppm sulfur) depends largely on the HDS of 4,6-dimethyldibenzothiophene (DMDBT), which is the least reactive sulfur compound in the product. The inhibiting effects of co-existing polyaromatics and nitrogen compounds in the feed, as well as H_2S in the product, aggravate the problem associated with deep HDS of diesel fuel.

The new trend in the development of catalysts is focused on achieving higher activity for hydrogenation to enhance 4,6-DMDBT conversion and higher activity for hydrodenitrogination (HDN) (for removal of nitrogen compounds at low concentrations). This development of catalysts, when coupled with more improved and severe reactor operating conditions, can improve deep HDS for meeting EPA's 2006 regulations, which limit sulfur in highway diesel by 2006 and in non-road diesel by 2010 to 15 ppmw. Tables 2.3.1 and 2.3.2 show the U.S. regulations of transportation fuels that have been promulgated by the Environmental Protection Agency (EPA) (Song, 2004).

Table 2.3.1: U.S. EPA's sulfur regulations for gasoline as of 2002

Category /Year	1989 (SAE, 1992)	1993 (EPA, 2003)	2006 (EPA, 2003)	2010 (EPA, 2003)
Highway diesel (ppmw)	5000 (maximum for no. 1D and 2D, with minimum cetane no. 40)	500 (current upper limit since 1993)	15 (regulated in 2001; exclude some small refineries)	15 (regulated in 2001; apply to all US refineries)
Non-road diesel (ppmw)	20000	5000 (current upper limit)	500 (proposed in 2003 for 2007)	15 (proposed in 2003 for 2010)
Jet fuel (ppmw)	3000	3000	3000 maximum	<3000 maximum

Table 2.3.2: US EPA diesel and fuel jet sulfur regulation as of April 2003

Category /Year	1988 (SAE, 1992)	1995 (Owen, 1995)	2004 (EPA, 2001)	2005 (EPA, 2001)	2006 (EPA, 2001)
Refinery average (ppmw)	1000 (maximum)	330 (<330 ppm S and <29.2% aromatics required for national certification; <850 ppm S and <41.2% aromatics as national maximum)		30	30
Corporate average (ppmw)			120	90	
Per-gallon cap (ppmw)			300	300	80

In 2001, Bezverkhyy et al. used highly dispersed MoS_2,supported on the surface of Al_2O_3, to study the HDS of thiophene. The activity increased linearly with Mo content up to 22 wt% of molybdenum sulfide. Co was used as a promoter, and Bezverkhyy found that HDS catalytic activity was much higher than that of a commercial, $CoMo/Al_2O_3$ catalyst.

Also, Genuit, in 2005, compared the activity of the highly dispersed Ni(Co)-Mo-S sulfides with commercial alumina-supported catalysts. The catalyst solutions were prepared at room temperature using nickel or cobalt salts and thiomolybdate precursors

in the presence of non-ionic surfactants. Genuit found that the specific catalytic activities of the systems were up to six times greater than those of commercial, alumina-supported systems.

In 1993, Eijsbouts et al. investigated the dispersion and homogeneity of two series of sulfidic, Al_2O_3–supported, Co-Mo and Ni-Mo catalysts, using transmission electron microscopy (TEM). They found that the hydrodesulfurization and hydrodenitrogenation activities of the catalyst samples were proportional to the MoS_2 dispersion. High MoS_2 dispersion has been reported in the high-activity commercial catalysts.

Another study was reported by Hou et al. (2004) in which it was found that Ni, Co, and Fe promoted the hydroprocessing reaction. The study addressed the upgrading of heavy petroleum feedstock in a slurry hydroprocessing reactor. The reaction was conducted at temperatures in the range of 290-370 ^oC and pressures in the range of 300 -1200 psig.

Yoosuk et al. (2008) reported that the promoted NiMo or CoMo sulfide showed higher liquid-phase adsorption selectivity for dibenzothiophene (DBT) than for 4,6-DMDBT. These promoters increased the activity of MoS_2 and changed the contribution of the direct-desulfurization and hydrogenation pathways. The HDS activity of the unsupported, Mo-based sulfides was found to be much greater than that of the sulfided, commercial $Co(Ni)Mo/Al_2O_3$ catalysts.

Besenbacher et al. (2008) conducted experimental and theoretical studies of both unpromoted MoS_2 and promoted Co-Mo-S and Ni-Mo-S nanostructures. These studies showed that the Ni-Mo-S structures may, in some instances, differ from the Co-Mo-S analogues. They reported that the important reaction steps may not involve vacancies, and special brim sites are seen to play an important role.

Recently, Gonzalesz-Cortes et al. (2008) studied trimetallic (NiCoMo and NiCoW) and bimetallic (NiMo, NiW, and CoMo) HDS catalyst precursors using a tubular, fixed-bed reactor for the hydrodesulfurization of thiophene at moderate pressure. The results showed that the addition of Co (or Ni) on Mo (or W) strongly improves the HDS activity.

However, using Ni and Co together hinders the HDS performance. This effect might be attributable to the formation of Ni-Co-S rather than Ni(Co)-Mo(W)-S phase (Gonzalez-Cortes et al., 2008).

Another experimental study of the slurry-phase hydrocracking of heavy oil using Fe and Ni as promoters for an MoS_2 catalyst was reported by Liu et al. (2009). They reported that the metal sulfides entered into the reactions with the free-radical intermediate formed on the catalyst surface. This could suppress coke deposition by reacting with the free radicals derived from the large molecules.

Egorova and Prins (2004) studied the effect of adding Ni and Co to the supported molybdenum sulfide catalyst in the HDS of DBT and 4,6- 4,6-DMDBT. It was found that the Ni and Co promoters strongly enhanced the activity of the Mo catalyst in the direct desulfurization pathway of the HDS of DBT and 4,6-DMDBT, as well as in the final sulfur-removal step in the hydrogenation pathway. The results showed that the relative promotional effect of Ni and Co on the Mo catalyst for HDS is dependent on the amount of H_2S present in the reaction (Egorova and Prins, 2004).

Ni-promoted catalysts perform better and give higher conversion of DBT than those of Co-promoted catalysts in the HDS of DBT (Rodríguez-Castellón et al., 2008). It is believed that the presence of sulfur anion vacancies (uncoordinated sites) on the Mo(W)–S_2 structure plays a major role in the HDS activity. They proposed that Ni and Co promote HDS because the promoter populates the edges of the Mo(W)S_2 to give Ni(Co)–Mo(W)–S-type structures (Rodríguez-Castellón et al., 2008; Topsøe et al.,1996; Eijsbouts et al,1993).

An experimental study was performed by Kantschewaa et al (1984) on a conventional $NiMo/Al_2O_3$ catalyst compared with same material after impregnation with K_2CO_3. This was to test the effect of K^+ ions on the catalytic performance of the $NiMo/Al_2O_3$ catalysts for thiophene hydrodesulfurization (HDS), ethylene hydrogenation, CO methanation, and water gas shift (WGS). The activity of HDS was reduced significantly in the presence of K^+ ions, while the activity for WGS was enhanced at the same time. Very

strong interaction of K^+ ions with the catalyst surface was noticed. It was suggested that the original octahedral coordination of Mo^{6+} in the $NiMo/Al_2O_3$ catalyst is changed into a tetrahedral coordination. It was also suggested that the presence of K^+ ions strongly decreased the reducibility of Mo^{6+}. It was found that the degree of sulfidation was reduced in $KNiMo/Al_2O_3$, this was accompanied by a stabilization of the Mo^{5+} oxidation state.

Sano et al (2004) reported that the removal of both nitrogen and refractory sulfur species in the gas oil was very effective to achieve its sulfur level of less than 10 ppm by the conventional HDS using CoMoS/silica–alumina catalyst. It was suggested that the sulfur content in the HDS product was governed by the nitrogen species in feed oil if its content was more than 60 ppm. It was suggested that the relationship between nitrogen contents of HDS feed oil and sulfur content of HDS product can be divided into two categories. At less than 60 ppm of nitrogen, low sulfur was found in the HDS product, while at more than 60 ppm N, the sulfur content in the HDS product is almost linearly related to the nitrogen content. Also it was reported that HDS is inhibited by the nitrogen species in 0.75 order and the refractory sulfur species in first order according to Langmuir–Hinshelwood type equation.

Chapter 3

Experimental Methods

3.1 Source of Materials

The treated and untreated samples of light gas oil were provided by Imperial Oil in June 2008. Untreated LGO was used as feed in the experiment as a model for bitumen, and treated LGO was used for comparison. Molybdenum oxide was used as the active site, which was sulfided by H_2S inside the reactor. Phosphomolybdic acid (PMA) ($12MoO_3 \bullet H_3PO_4 \bullet xH_2O$), which was supplied by Aldrich Chemical Co., was used as a catalyst precursor.

The main reaction gases used were CO, H_2, H_2S, and N_2. CO was used to produce in-situ H_2 via the WGSR. Molecular H_2 was used as the pure H_2 reaction medium. Catalyst sulfiding was done using H_2S. N_2 was used for thermal cracking and for leak testing. All gases were supplied by Praxair.

3.2 Procedure

Most of the experiments were conducted in a 300-cm^3 batch-autoclave, stainless steel reactor. The reactor was charged with 100 ml of LGO and catalysts that amounted to 1500 ppm of the total organic mass. Ten milliliters of de-ionized water were added to react with the CO. A seal between the reactor lid and body was created by using a metal o-ring. The gland-retaining ring was sprayed with molykote lubricant to enhance reactor sealing, dried for 20 minutes, and then placed in the groove. Then, the magnedrive was slipped into the reactor, and the six screws were tightened in a criss-cross manner, using a 35 ft-lb torque wrench in increments of 3 ft-lbs for the first 21 ft-lbs, followed by increments of 5 ft-lbs. The tachometer and gas sampling line were installed. The water lines and thermocouples were then attached.

After purging the lines with nitrogen, a leak test was conducted by charging the reaction system with nitrogen to a pressure of 1000 psi. Temperature and pressure were recorded. The system pressure was monitored for an hour to ensure that there were no gas leaks. Then, CO was charged to the reactor to a pressure of 300 psi to purge the N_2, and this purging was repeated three times. Then, H_2S was introduced to the system until the pressure was 10 psi. Then, the system was pressurized with CO up to 600 psi for the water-gas shift reaction to take place for the reference case (Run # 11 LGOR2).

The reaction was initiated by turning on the furnace and the stirrer so that a reaction temperature around 390 ^oC was achieved. Also, cooling water and the ramping program were started, and the main parameters were read and recorded every 15 minutes. The reaction was allowed to continue for two hours. When the reaction was completed, the furnace was turned off, and the stirrer was stopped. Then, gas samples were collected for analysis by the Agilent Refinery Gas Analysis (RGA) micro-GC. The liquid samples collected were analyzed using Varian CP-3800 Gas Chromatography and an Oxford XRF spectrometer.

3.3 Set up

Experiments were performed in a 300 cc AISI 316 stainless steel batch, bolted pressure vessel manufactured by AE Autoclave Engineers. The working volume of the reactor is 249 ml. The reactor is equipped with a Magnedrive assembly stirrer and a 45 º pitch impeller which extends to 88 % of the reactor depth (Figure 3.3.1).

The system was heated to the desired reaction temperature using a shell heater controlled by a Honeywell Universal Digital Controller (UDC-200 Mini Pro). The temperature in the lower regions of the reactor is measured using Omega K-type 1/32“in diameter subminiature thermocouple. The thermowell reached 13.3 cm into the 19.7 cm reactor cavity. Omega pressure transducer model PX-300 measured the system pressure. A snubber is used in front of the pressure transducer to protect the sensor crystal. Cooling water is used to cool the reactor head.

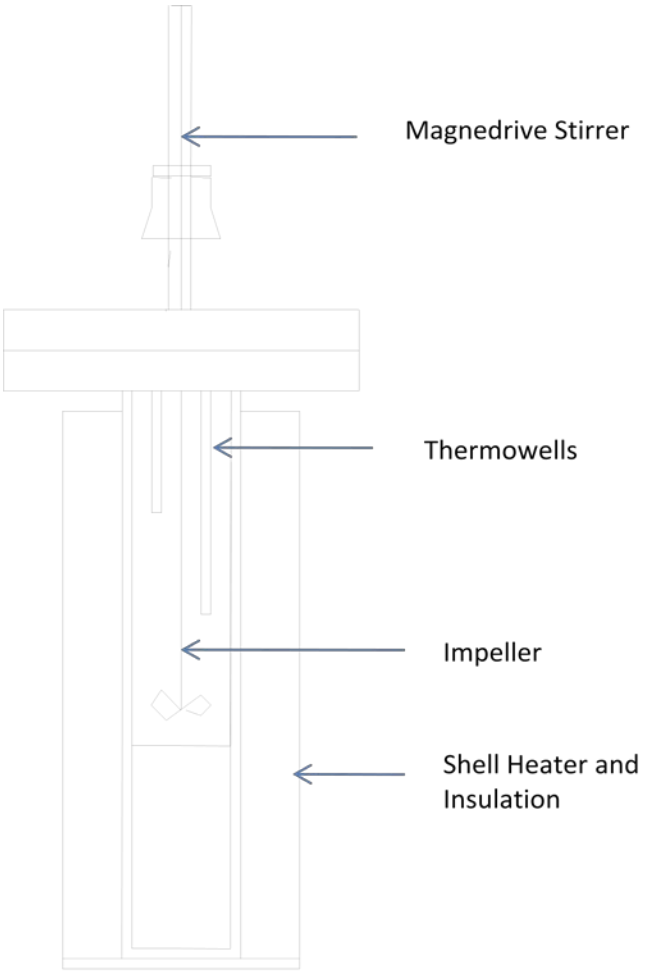


Figure 3.3.1 Schematic diagram of the 300 cc reactor

Figure 3.3.2: Image of the 300ml batch reactor

3.4 One Liter Reactor

A 1L batch autoclave reactor was used to perform selective experiments in which liquid samples can be collected while the reaction is taking place. All of the reaction conditions were the same as in the smaller reactor (the 300cm^3 reactor), and the ratios of the feed, gas and catalysts were maintained by raising the quantities of the feed three times. The major difference here is the volume of the reactor.

The liquid and gas samples were collected every 30 minutes from the liquid phase in the reactor. The gas samples represented the dissolved in the reaction medium. Both gas and liquid cooled down using cooling water coils around the sampling port. After few minutes, the samples were sent to a small bomb for separation. Then, gas was sent to the gas port and collected from the gas holder. After venting the sampling system, liquid samples were drained by gravity and collected in vials. Collected liquid then filtered and the organic phase was separated and analyzed. Schematic diagram of the sampling system is shown in Figure 3.4.3.

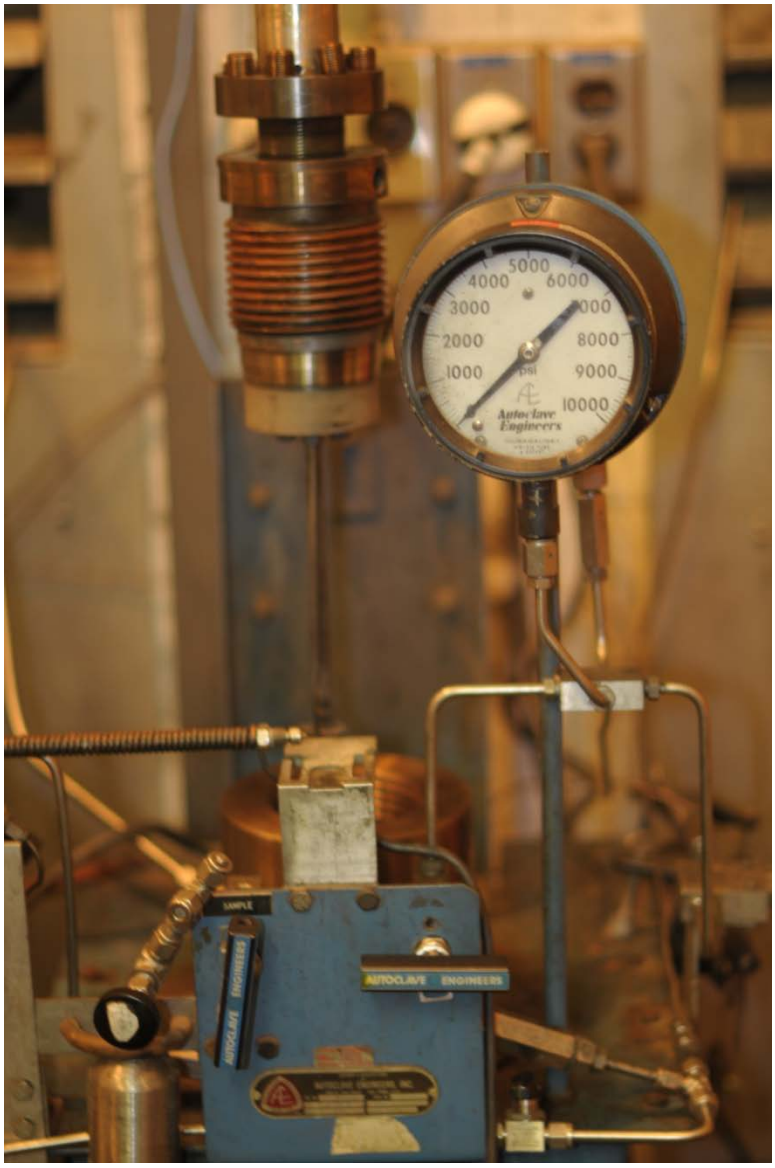


Figure 3.4.1: Photograph of the one liter batch reactor

Figure 3.4.2: Photograph of the head assembly of 1L reactor

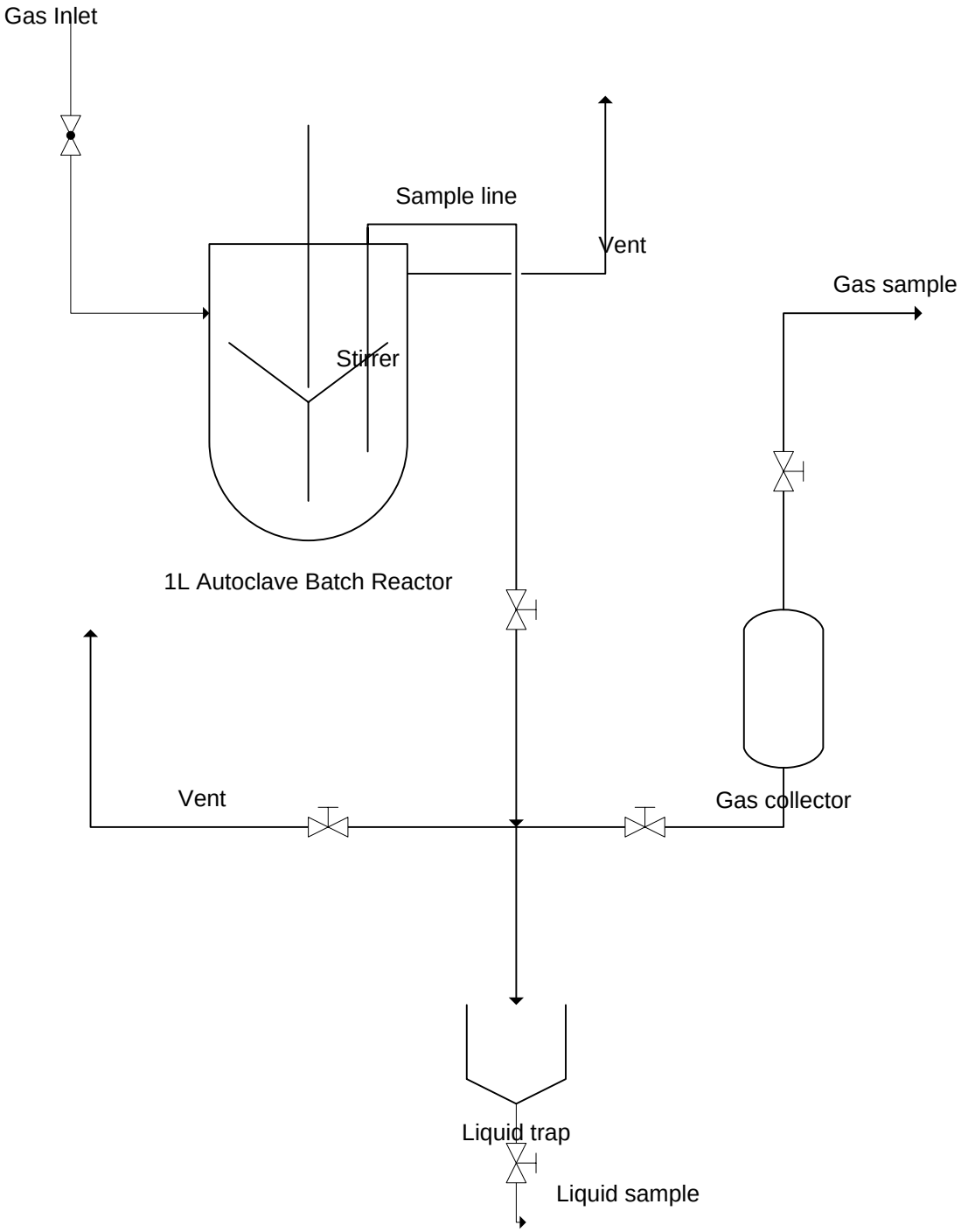


Figure 3.4.3: Schematic diagram of the 1L reactor's sampling system

3.5 Analytical Methods

An Agilent 3000A micro-GC was utilized for gas analysis. The gases products were collected in a gas bag. The GC was calibrated frequently using a standard Refinery Gas Analysis (RGA) calibration mixture supplied by Agilent.

The liquid product was analyzed for the type of sulfur compound using a Varian CP-3800 GC Pulsed Flame Photometric Detector (PFPD) with a 30 m x 0.32 mm VF-5MS column. Sulfur content analysis was carried out using Lab-X 3000S X-Ray Fluorescence (XRF) Spectrometer. The XRF was calibrated using DBT and toluene (Calibration curve is shown in Appendix B). Simulated Distillation was also used to analyze the boiling point range of the liquid product using an Agilent GC according to ASTM-D2887 method. Agilent Technology GC Chemstation (online and offline) software were used.

3.6 Calculations

3.6.1 WGSR

The calculation of CO conversion is based on the change of total moles of CO before and after the reaction determined using the Agilent Refinery Analyzer:

$$X_{CO}(\%) = \left[\frac{(N_{CO})_i - (N_{CO})_f}{(N_{CO})_i}\right] \times 100$$

Where,

$(N_{CO})_i$ = initial moles of CO

$(N_{CO})_f$ = final moles of CO

N is the number on moles calculated based on the ideal gas law:

$$N = \frac{PV}{RT}$$

where,

P= pressure (atm), V=Total working volume, R=gas constant (0.08206 atm L/mole K), T= Temperature (K)

H_2 generated via WGSR was calculated as follows:

$H_2 generated = (N_{CO})_i - (N_{CO})_f$ According to the stoichiometry of the water gas shift reaction

3.6.2 Catalyst loading

From Table 3.6.1, the amount of Mo in PMA can be calculated as follows;

$$1825.279\ \frac{gPMA}{\cancel{mol\ PMA}}\ x\ \frac{1\ \cancel{mol\ PMA}}{12\ \cancel{mol\ Mo}}\ x\ \frac{1\ \cancel{mol\ Mo}}{95.942\ g\ Mo} = 1.5854\ \frac{g\ PMA}{g\ Mo}$$

Mass of Mo needed to have 1500 ppm Mo to the total organic mass (mass of LGO =88.94 g from run#19) is;

$$88.94\ x\ 1500\ x\ 10^{-6} = 0.13341\ g\ Mo \qquad (3.6.1)$$

Mass of PMA needed = $0.13341\ g\ Mo\ x\ 1.5854\ \frac{g\ PMA}{g\ Mo} = 0.2115\ g\ PMA$ (3.6.2)

Number of moles of Mo needed =

$$0.13341\ \cancel{g\ Mo}\ x\ \frac{mol\ Mo}{95.42\ \cancel{g\ Mo}} = 0.00139\ mol\ Mo \qquad (3.6.3)$$

Number of moles of Ni needed to have 0.6 mole ratio to Mo is;

$$0.00139\ mol\ Mo\ x\ 0.6 = 0.000834\ mol\ Ni \qquad (3.6.4)$$

MW of Ni precouser ($NiSO_4x6H_2O$) is 262.86 g/mol

Mass of Ni sulfide needed =

$$0.000834\ \cancel{mol\ Ni}\ \ x\ \frac{1\ \cancel{mol\ NiSO4}}{1\ \cancel{mol\ Ni}}\ x\ \frac{262.86\ g\ Ni\ SO4}{1\ \cancel{mol\ NiSO4}} = 0.2193\ g\ NiSO4 \quad (3.6.5)$$

Amount of water containing in NiSO4x6H2O is;

$$0.000834\ \cancel{mol\ Ni}\ x\ \frac{1\ \cancel{mol\ NiSO4}}{1\ \cancel{mol\ Ni}}\ x\ \frac{6\ \cancel{mol\ H2O}}{1\ \cancel{mol\ NiSO4}}\ x\ \frac{18\ g\ H2O}{1\ \cancel{mol\ H2O}} = 0.0901\ g\ H2O \quad (3.6.6)$$

Table 3.6.1: Elemental composition of $H_3Mo_{12}O_{40}P$ (PMA)

Symbol	Element	Atomic weight	Number of atoms	Mass	Mass Fraction	Mass percent
H	Hydrogen	1.007947	3	3.023841	0.001657	0.17%
Mo	Molybdenum	95.942	12	1151.304	0.630755	63.08%
O	Oxygen	15.99943	40	639.9772	0.350619	35.06%
P	Phosphorus	30.97376	1	30.97376	0.016969	1.70%
	TOTAL =	**143.9231**		**1825.279**		

Chapter 4

Results and Discussion

4.1 Effect of Promoters on the WGSR and HDS of LGO

The effect of five different promoters, namely; nickel, cobalt, iron, vanadium, and potassium on the WGSR and HSD of LGO were investigated. Nickel (Ni) and cobalt (Co) are common promoters of the HDS reaction, while iron (Fe) and vanadium (V) were investigated because they are associated with heavy oil. Zhang (2005) investigated the effect of adding Ni to Mo for the WGSR and naphthalene hydrogenation. The experiments, carried out with different mole ratios of Ni to Mo (0, 0.15, 0.3, 0.6, 0.8 and 1), revealed that the optimum mole ratio of Ni:Mo was 0.6:1. This molar ratio will be the basis of calculating the amount of promoters in this study.

Table 4.1.1 lists the experimental runs performed to study the effect of these promoters on the WGSR and HDS reactions. All experiments were performed using 100 ml LGO with 10 vol% water under CO at 391°C (Table 4.1.2). In each of the five experiments, 0.6:1 mole ratio of the promoting metal to Mo was used, and the catalyst precursors used are listed in Table 4.1.3. All of the experiments were performed in the Autoclaves Engineer 300 ml batch reactor. (Details of the product analysis , temperature and pressure data are shown in Appendix C)

Table 4.1.1 List of the experiments carried out to study the effect of different promoters on the WGSR and HDS

Run #	Run ID	Reactor Volume	Objective
19	LGONi2	300 ml	To treat LGO with Mo promoted with Nickel
9	LGOCo	300 ml	To treat LGO with Mo promoted with Cobalt
11	LGOR2	300 ml	To treat LGO with un-promoted Mo
14	LGOFe	300 ml	To treat LGO with Mo promoted with Iron
20	LGOV2	300 ml	To treat LGO with Mo promoted with Vanadium
22	LGOK	300 ml	To treat LGO with Mo promoted with Potassium

Table 4.1.2 Reaction conditions for the investigation of the effect of promoters on the WGSR and HDS

Common operating conditions	
Volume of LGO	100 ml
Mo content	1500 ppm
Reaction time	2 hrs
Reaction temperature	391 ^{o}C
H_2S Loading	10 psi
Gas Medium	CO (590psi)

Table 4.1.3 Catalyst precursors used for the different promoters

Catalyst	Precursor	(ppm) of promoter
Ni-Mo	PMA + $NiSO_4$	500
Co-Mo	PMA+ $CoSO_4$	500
Mo	PMA	
Fe-Mo	PMA + $FeSO_4$	500
V-Mo	PMA + $C_{10}H_{14}O_5V$	500
K-Mo	PMA + K_2CO_3	500

Ni and Co are known as common HDS promoters because the promoters populate the edges of $Mo(W)S_2$ with the so-called Ni(Co)–Mo(W)–S type structures (Besenbacher et al. ,2008; Gonzalez-Cortes, 2008). XRF results show that the amount

of sulfur (S) removed using these two promoters is higher than that removed using un-promoted molybdenum sulfide catalysts. Ni was found to be the best promoter because more than half of the feed sulfur was removed (Figure 4.1.1). On the other hand, V and potassium (K) were found to be inhibitors of the HDS reaction; K is a particularly strong inhibitor because no HDS was observed. It was also observed that added Fe did not improve the HDS reaction and that there was no significant change in the activity compared to the un-promoted Mo catalyst. Table 4.1.4 shows the amount of sulfur in the product detected by x-ray fluorescence using different promoters.

So far, the comparison was based on the added promoters to the experiment with 1500 ppm Mo. Hence, another experiment with 2000 ppm Mo was carried out to simulate the total metal loading for comparison with the other promoters. The XRF results revealed that there is an increase of the HDS activity compared to experiment with 1500ppm Mo. In fact, the increase in S removal is directly proportional to the Mo loading suggesting a first order dependence of S removal on the Mo content. Although a higher S removal was observed at 2000 ppm Mo compared to the experiment with added Co, Ni promoted Mo still has the highest HDS activity.

Four experiments were repeated to confirm the reproducibility of the results. Sulfur contents and RGA analysis were mainly compared and found to be comparable. Reproducibility of the runs is shown in Appendix A.

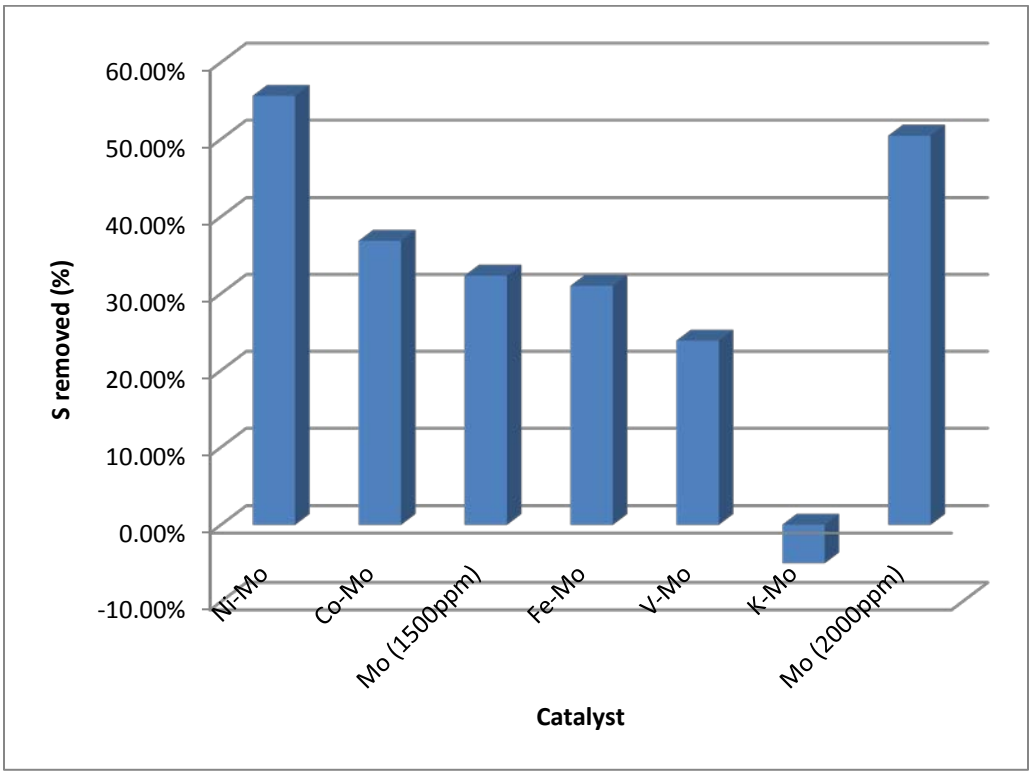


Figure 4.1.1: Effect of promoters on sulfur removal

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

Table 4.1.4 Sulfur removal using different promoters

Catalyst	S in feed (ppm)	S in product(ppm)	% S removal
Ni-Mo	24407.63	10828.91	55.64%
Co-Mo	24407.63	15412.14	36.86%
Mo (1500ppm)	24407.63	16517.34	32.33%
Mo (2000ppm)		14513.99	40.54
Fe-Mo	24407.63	16840.05	31.00%
V-Mo	24407.63	18581.12	23.87%
K-Mo	24407.63	25703.03	-5.00% *

*within experimental error

The GC analysis for the sulfur compounds in the liquid product using a Varian CP-3800 GC-PFPD confirms that Ni is the most effective promoter. Figures 4.1.2-4 show that the concentration of different sulfur compounds is the lowest when Ni was added while K showed an inhibiting effect. There are many sulfur compounds existing in the liquid samples, but we have identified only benzothiophene (BT), dibenzothiophene (DBT) and 4, 6- , dimethdibenzothiophene (4, 6, DMDBT).

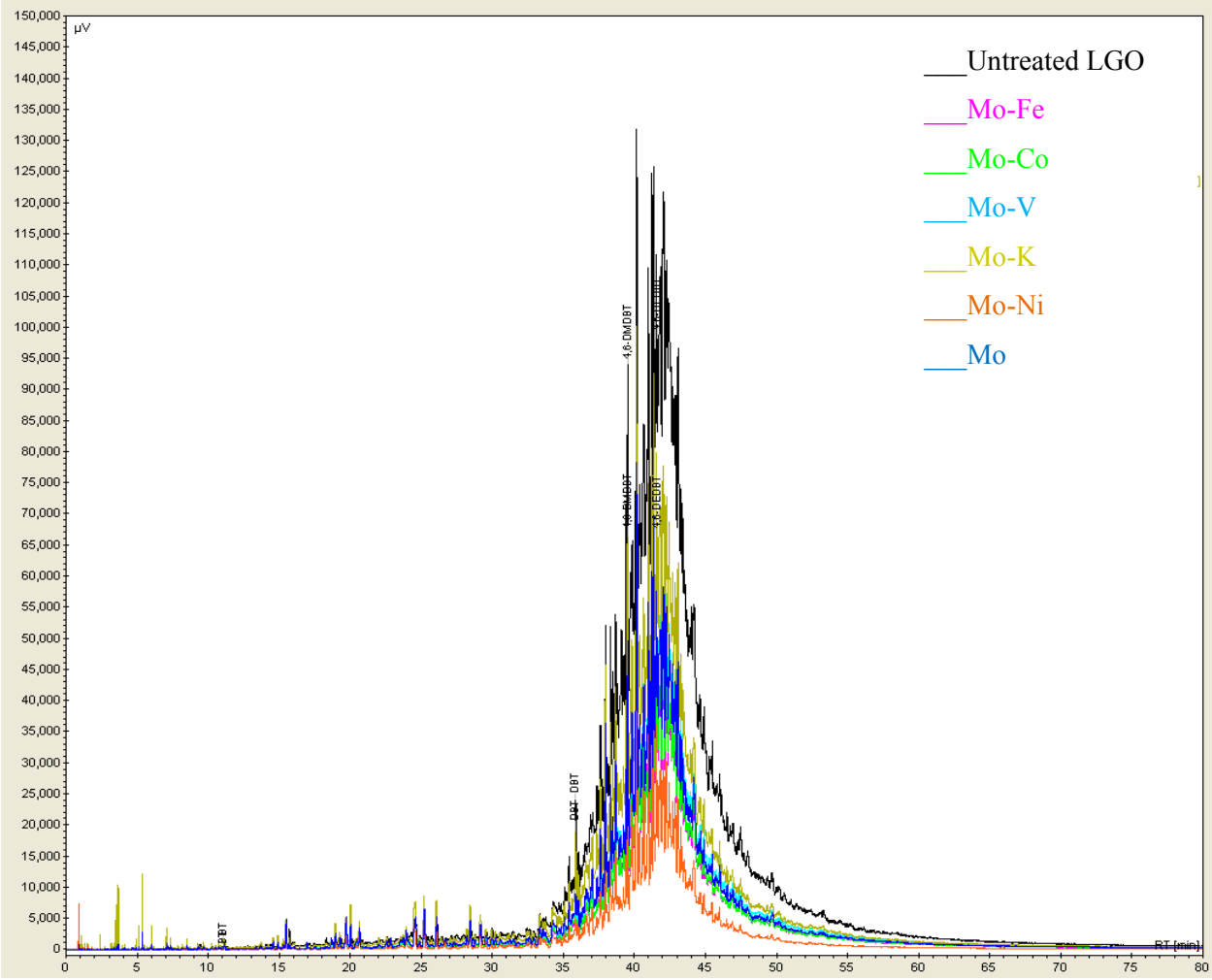


Figure 4.1.2: GC analysis of sulfur compounds in the liquid product

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

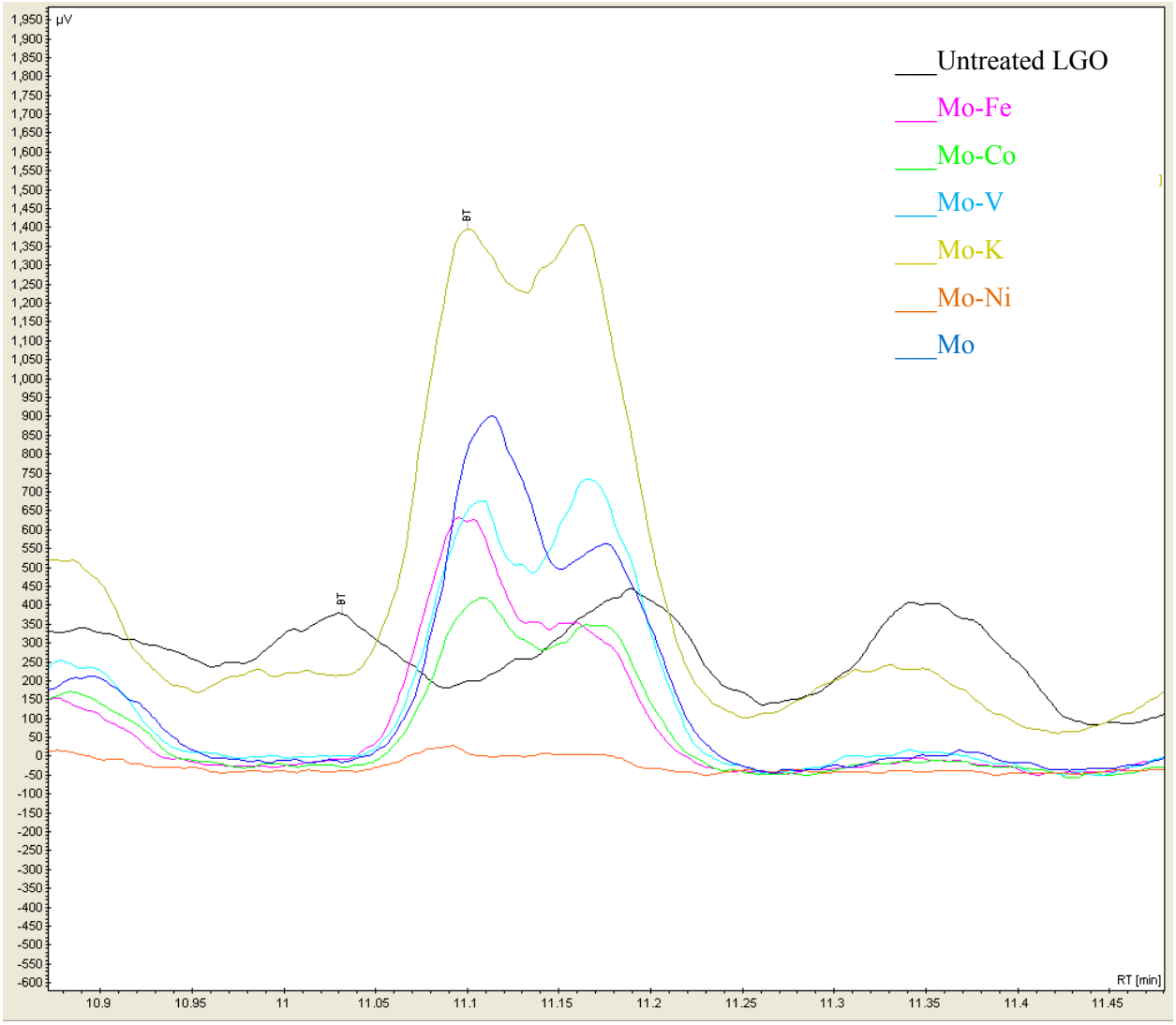


Figure 4.1.3: Concentration of BT in the liquid product

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

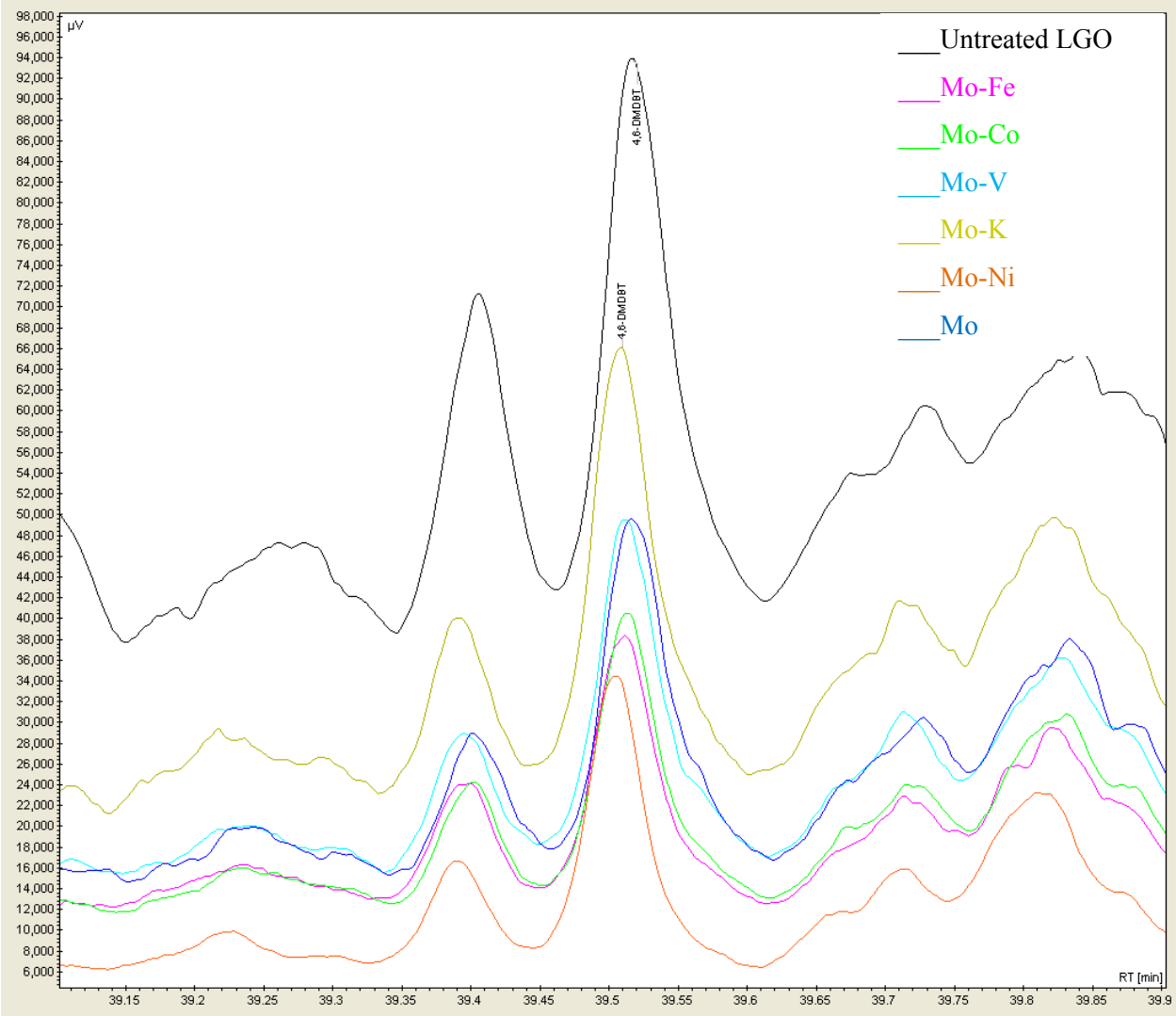


Figure 4.1.4: Concentration of 4,6 DMDBT in the liquid product

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

The conversion of CO calculated from RGA gas analysis showed that Ni and Co promoted the WGSR and that V and K were even better promoters for the WGSR, although they inhibited the HDS reaction as shown in Figure 4.1.5.

Potassium was found to be the best WGSR promoter but also the strongest HDS inhibitor. This is consistent with the study of Kantschewaa et al (1984) where the activity of HDS was reduced significantly in the presence of K^+ ions, while the activity for WGS was enhanced at the same time. It was suggested that the original octahedral coordination of Mo^{6+} in the $NiMo/Al_2O_3$ catalyst is changed into a tetrahedral coordination. It was also suggested that the presence of K^+ ions strongly decreased the reducibility of Mo^{6+}. It was found that the degree of sulfidation was reduced in $KNiMo/Al_2O_3$.

Fe was once again neutral, and there was no significant change on the sulfur removal and CO conversion compared to Mo itself (Figure 4.1.5). Actually, the gas analysis results show the gas composition namely CO, H_2, CO and H_2S for the Fe promoted Mo is very similar to that for Mo alone (Figures 4.1.6 and 4.1.7). Higher amount of H_2S was detected with Ni and Co promoted Mo suggesting higher HDS activities for these two catalysts. For K promoted Mo, some H_2S was detected suggesting no H_2S was consumed in the sulfidation process. The initial loading of was 1.67 mole % while the RGA analysis for gas products showed 2.1 mole % which is more than the initial loading.

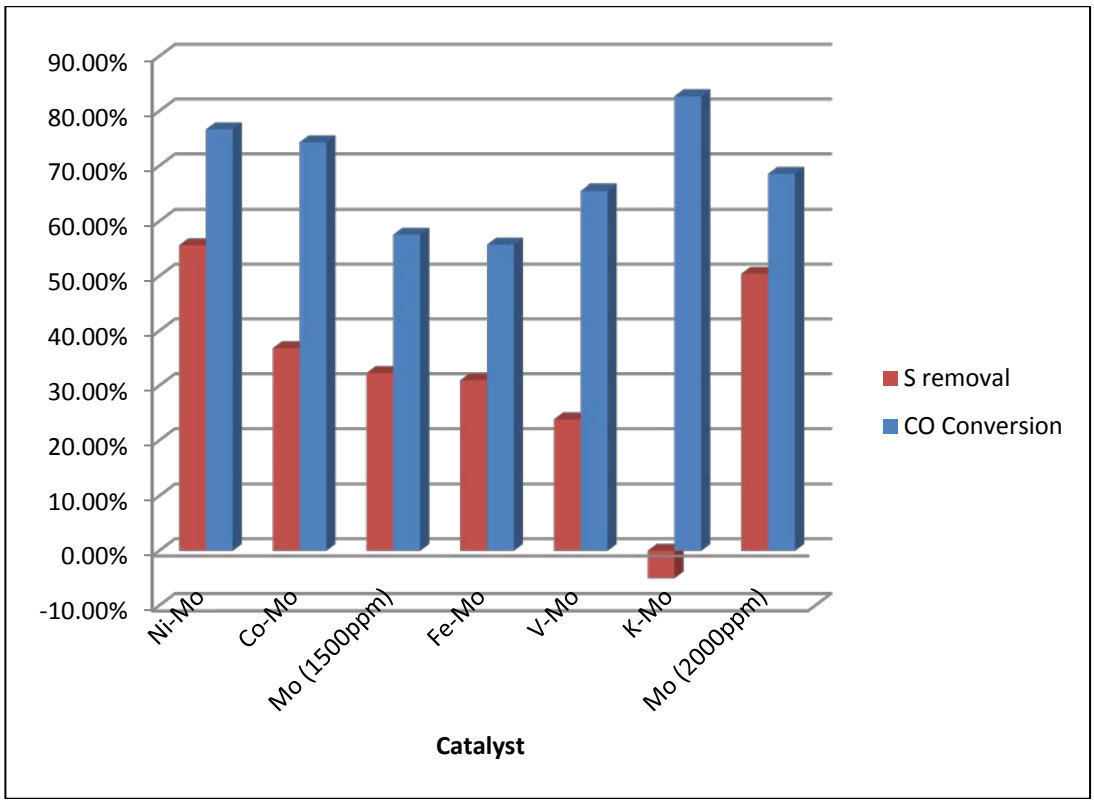


Figure 4.1.5: Effect of promoters on HDS and WGSR.
Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

Table 4.1.5 RGA analysis for different promoters

Catalyst	H_2 (mol %)	CO (mol %)	CO_2 (mol %)
Ni-Mo	19.1	16.6	54.5
Co-Mo	18.5	18.1	52.4
Mo (1500ppm)	26.5	28.9	39.2
Mo (2000ppm)	22.5	22.1	48.2
Fe-Mo	26.5	30.2	38.0
V-Mo	28.5	22.7	43.2
K-Mo	34.8	10.4	49.8

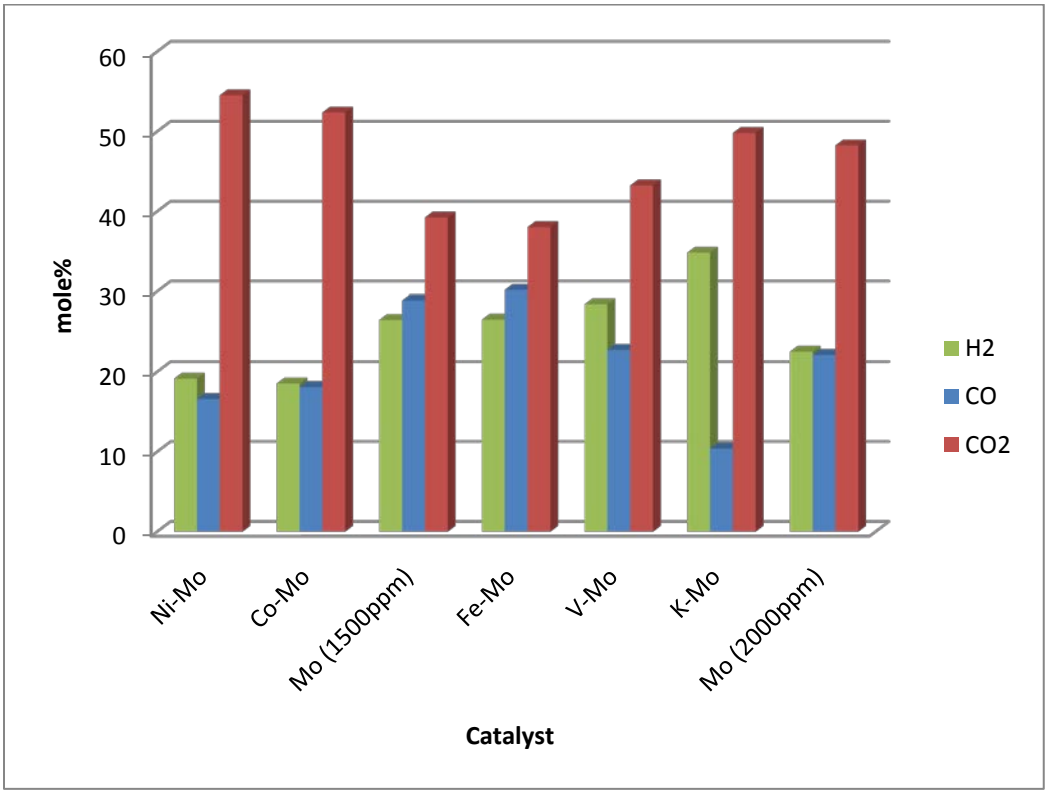


Figure 4.1.6: Compositions of gas product.

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

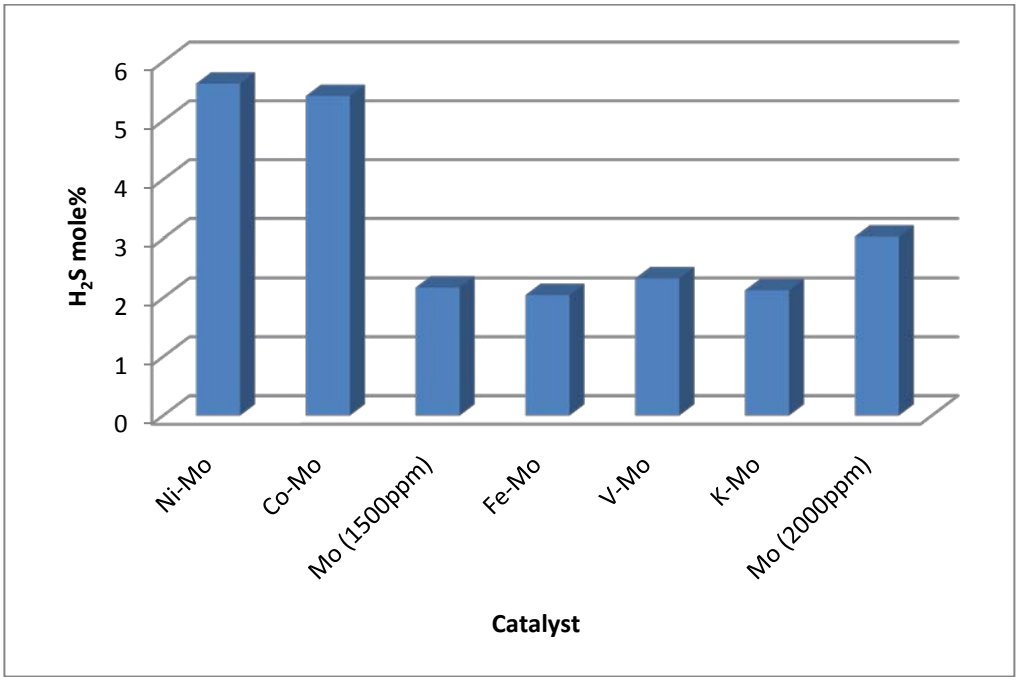


Figure 4.1.7: H_2S in gas product.
Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^oC reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 0.6 to 1 mole ratio of metal to Mo

Simulated Distillation (SimDis) was carried out to determine the effect of different promoters on the product quality. As boiling point ranges suggest, there was no significant difference between the liquid products in all of these experiments (Figure 4.1.8). This is might be attributed to the narrow boiling range of the feed (untreated LGO B.P 200-450^oC) and that no significant cracking occurred at 391 °C. The results also revealed an improvement in the boiling point range of the treated oil compared to the untreated one where 80% of the pitch fraction was converted to lighter cuts. It is important to note that although the promoters provide different degrees of S removal, the pitch conversions and the boiling fractions are very similar for all promoters except Ni-Mo produced most naphtha. Therefore S removal does not necessary correspond to pitch conversion or the distribution of the naphtha, kerosene, distillate and heavy gas oil fractions. Figure 4.1.9 shows a comparison between the treated, untreated LGO samples provided from a commercial plant and the LGO treated in the lab without

promoters. The boiling point ranges shows an increase in naphtha cut of the treated LGO compared to the untreated one. It is also shown the conversion of pitch to lighter materials in the treated LGO. The pitch conversion was found to be 80%. Table 4.1.6 shows the percentage of each cut with different promoters in addition to the untreated LGO sample.

Table 4.1.6: SimDis results for different promoters

Cut	Naphtha (%)	Kerosene (%)	Distillate (%)	Heavy Gas Oil (%)	Pitch (%)
B.P range ^{o}C	< 204	204 - 288	288 - 343	343 - 524	> 524
Mo-Ni	11	25	26	35	2.5
Mo-Co	9	28	24	36	2.5
Mo	10	28	24	35	2.5
Mo-Fe	8	28	25	36	2.5
Mo-V	10	26	25	36	2.5
Mo-K	8	28	24	37	2.5
Untreated	6	23	23	35	12.5

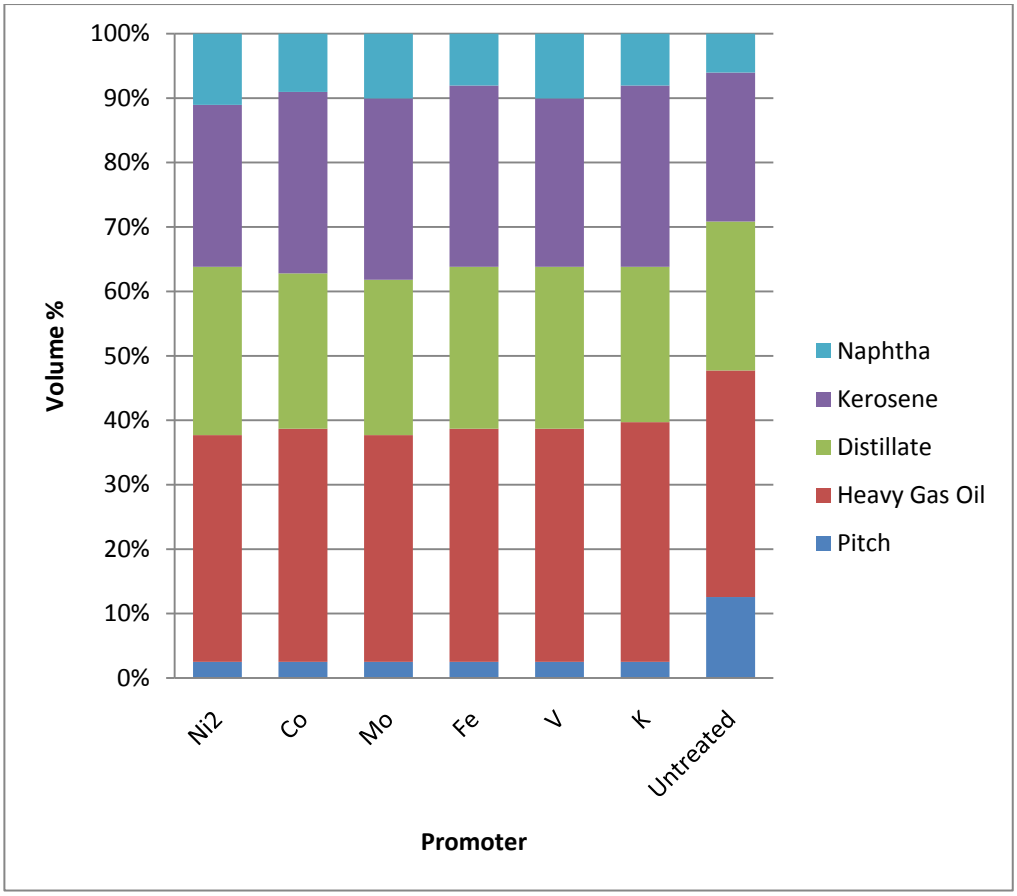


Figure 4.1.8: Boiling point distribution.

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 500 ppm promoter

Boiling point ranges: naphtha (<204 ^{o}C), kerosene (204-288 ^{o}C), distillate (288-343 ^{o}C), heavy gas oil (343-524 ^{o}C), pitch (>524 ^{o}C)

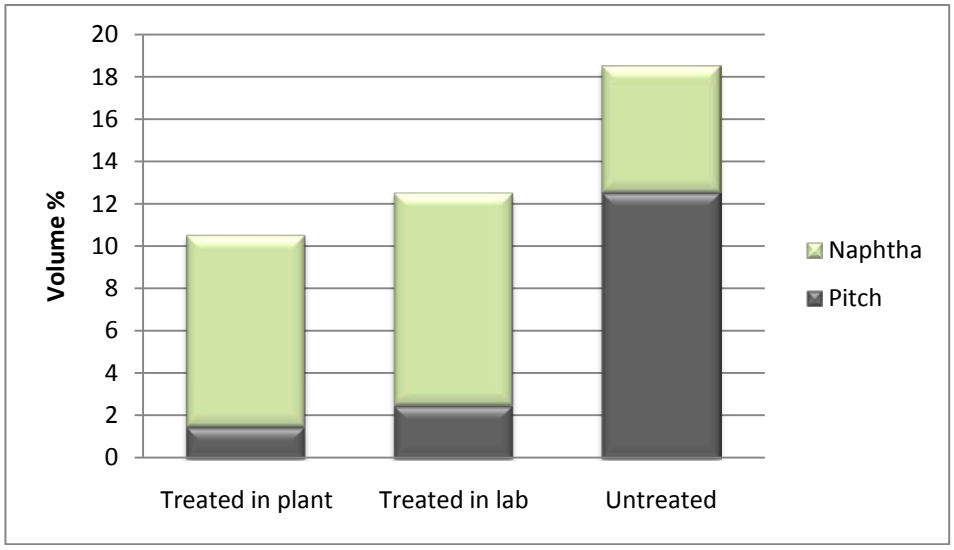


Figure 4.1.9: Naphtha and pitch cuts in treated and untreated samples

Conditions; 100 ml LGO, 10 ml water, time 2hs, 391 ^{o}C reaction temperature, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo, 500 ppm promoter

Boiling point ranges: naphtha (<204 ^{o}C), kerosene (204-288 ^{o}C), distillate (288-343 ^{o}C), heavy gas oil (343-524 ^{o}C), pitch (>524 ^{o}C)

4.2 Effect of water content and gas medium

Water is associated with emulsion, which needs to be dewatered first as part of the conventional upgrading process. WGSR can be utilized in a bitumen emulsion upgrading process by reacting the water with CO or syn-gas. The water associated with emulsion could be used to produce in-situ hydrogen instead of a separate step of emulsion breaking dewatering the emulsion and then using expensive molecular hydrogen for hydrotreating processes. Water is essential because it reacts with CO to produce in-situ H_2 via the WGSR and, at the same time, water inhibits the HDS reaction, which is a bottleneck in the upgrading process of bitumen emulsion. Hence, it is necessary to find the optimum amount of water needed to perform both reactions under different gas atmosphere.

In Lee and Ng's study (2006), the in-situ H_2 was more active than molecular-supplied H_2 for sulfur removal at the optimized mole ratio of H_2O:CO (1.35). The study indicated under CO where in-situ H_2 was produced, the hydrogenation/elimination pathway in the HDS of DBT was preferred.

The main purpose of these experiments is to study the effect of water content on HDS and WGSR under the two different gases media. Three different amounts of water—5, 10, and 15 ml to 100 ml of LGO—were tested under CO (in-situ H_2) and H_2 (molecular H_2), as shown in Table 4.2.1. All the experiments were carried out in the 300ml Autoclave Engineer batch reactor for 2 hours at 391^{o}C. (Table 4.2.2)

Table 4.2.1 List of the experiments carried out to study the effect of water and gases medium on the WGSR and HDS

Run #	Run ID	Reactor Volume	Objective
3	LGO5W	300 ml	To treat LGO with 5ml water under CO
11	LGOR2	300 ml	To treat LGO with 10ml water under CO
23	LGO15W	300 ml	To treat LGO with 15ml water under CO
7	LGOH5W2	300 ml	To treat LGO with 5ml water under H_2
10	LGOH2	300 ml	To treat LGO with 10ml water under H_2
24	LGOH15W	300 ml	To treat LGO with 15ml water under H_2

Table 4.2.2 Reaction conditions to study the effect of water and gases medium on the WGSR and HDS

Common operating conditions	
Reaction time	2 hrs
Reaction temperature	391 ^{o}C
H_2S Loading	10 psi
Feed	100 ml LGO
Catalyst	1500ppm Mo

The sulfur content of the filtered liquid samples were analyzed by XRF (Oxford Lab X-3000S) for sulfur analysis. XRF results showed that the amount of sulfur removed using in-situ H_2 was more than the amount of sulfur removed using molecular H_2 when 5 and 10 ml of water were used. When 15 ml of water used, molecular H_2 performed better than in-situ H_2, which indicates that, when the amount of water exceeds a certain value, it inhibits the HDS reaction more when CO is used than when molecular H_2 is used. This result is similar to the finding of Siewe and Ng (1998) when they used around 30 vol% of water to treat diesel sample and found that H_2 performed better than in-situ hydrogen.

This result could be attributed to the inhibiting effect of water under the two different gas media.

Overall, the HDS activity is inversely proportional to the amount of water, and the best result was obtained when 5 ml of water to LGO was used. It was also found that water inhibited the HDS slightly more with CO than with molecular H_2 at 15 ml of water. However, the difference is perhaps within the experimental error. (Figure 4.2.1)

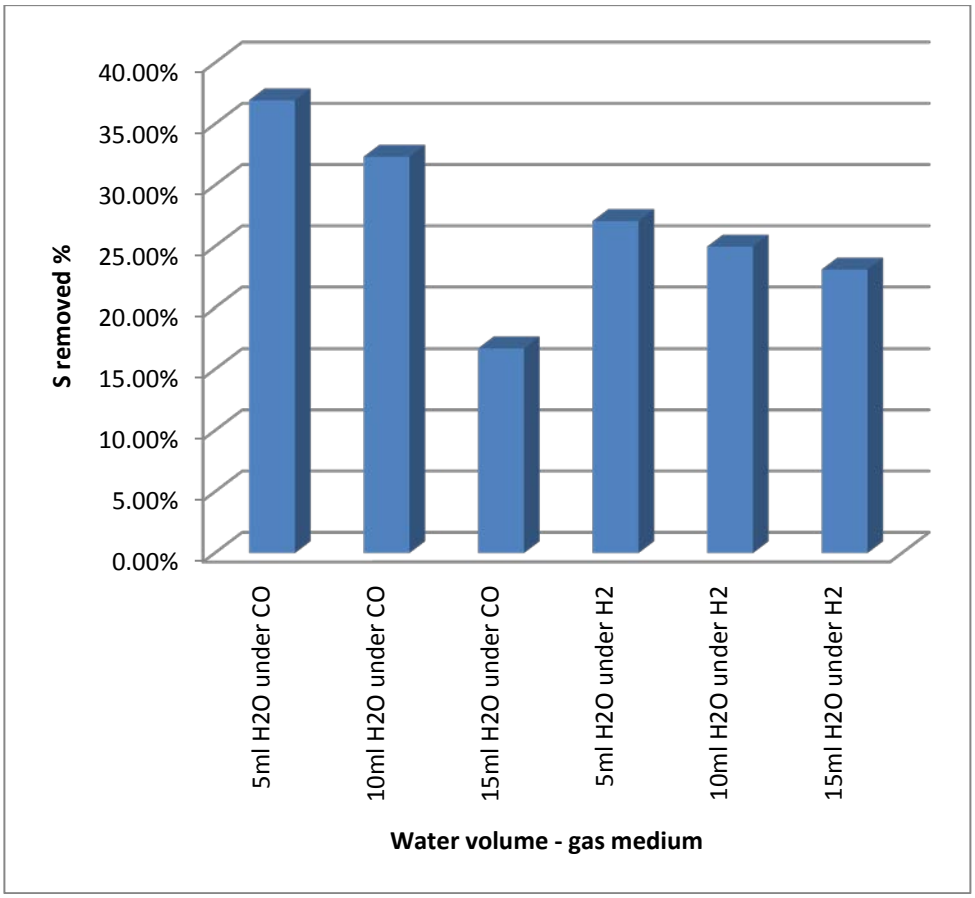


Figure 4.2.1: Effect of water and medium on sulfur removal.
Conditions; 2hr, 391°C, 100ml LGO and 1500ppm Mo, 590 psi gas loading

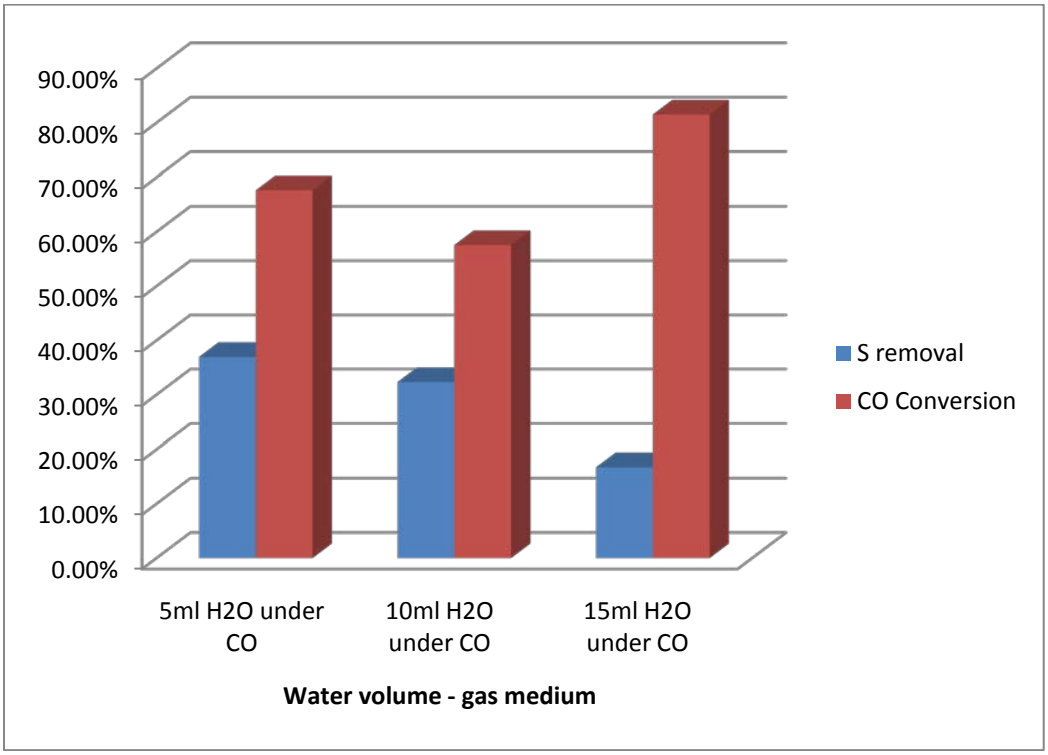


Figure 4.2.2: Effect of water on HDS and WGSR under CO.
Conditions; 2hr, 391°C, 100ml LGO and 1500ppm Mo

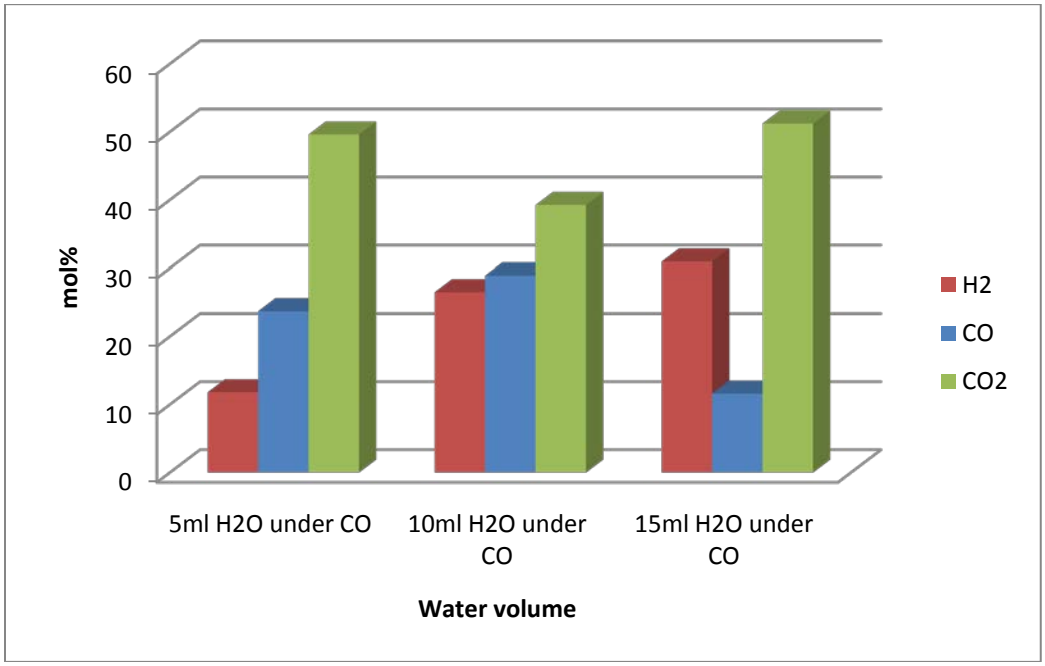


Figure 4.2.3: Gas analysis for different water content under CO.
Conditions; 2hr, 391°C, 100ml LGO and 1500ppm Mo

Gas analysis revealed that the CO conversion is lower when 5 vol% of water was used than 10 vol% of water, and the highest conversion was achieved at 15% (Figure 4.2.2). It is also shown in Figure 4.2.3 that mole H_2 presented in the gas phase increased with water content while moles of CO decreased. It was found that the amount of water content under these conditions is proportional to the WGSR activity and inversely proportional to the HDS activity. That suggests the excess water which was not consumed in the WGSR inhibited the HDS. Figure 4.2.4 shows the amount of water remained after reaction in each experiment. Values were representing the percentage of remaining water compared to the initial amount of water. It is shown that excess water is inversely proportional to the amount of sulfur removed which can be attributed to the inhibition effect of water on the HDS.

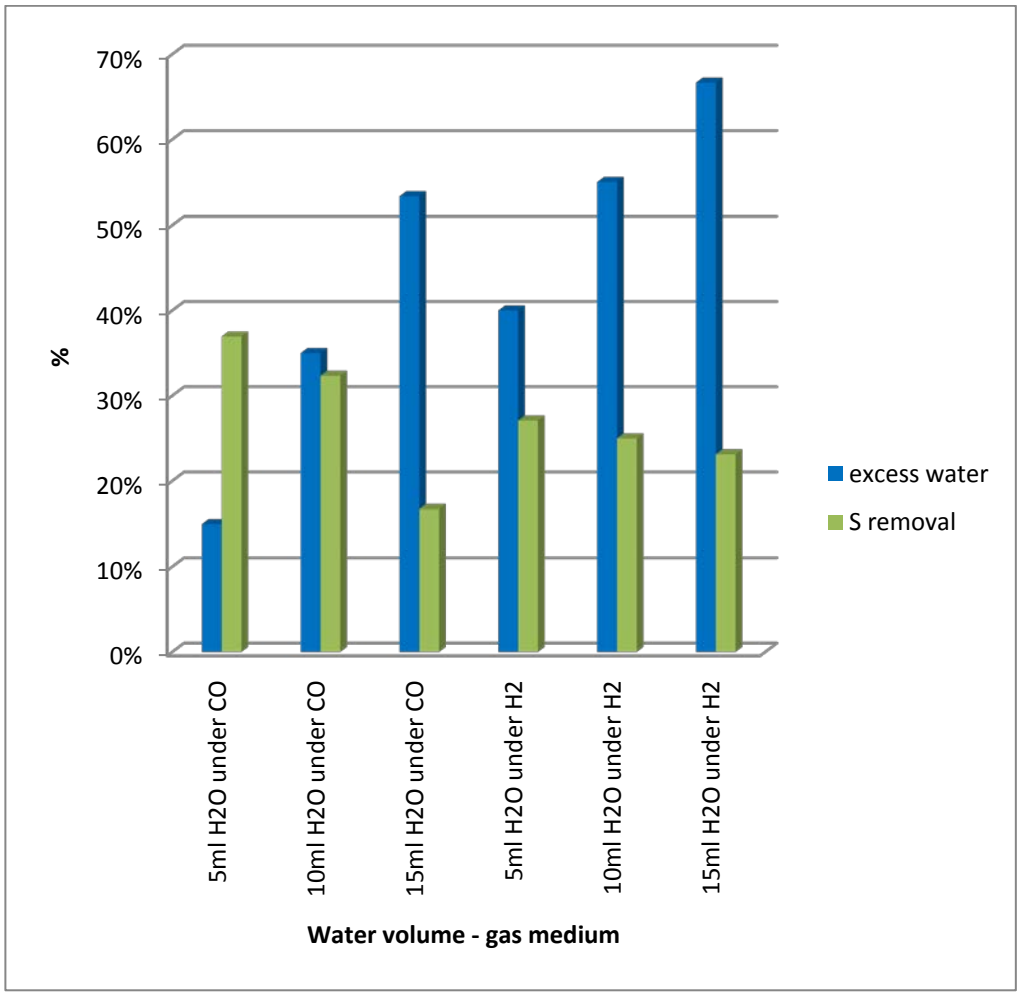


Figure 4.2.4: The relation between excess water and HDS

Conditions; 2hr, 391^{o}C, 100ml LGO and 1500ppm Mo

4.3 Effect of syn-gas composition

The purpose of this series of experiments is to investigate the effect of different synthesis gas compositions on both WGSR and HDS reactions. Initial loading of CO compared to the total initial pressure of both CO and H_2 was varied at 100, 60, 30, and 0 percent (Table 4.3.1). All of these experiments were performed in the 1 liter Autoclave Engineer batch reactor at the same reaction temperature, time duration and feed (Table 4.3.2). Liquid and gas samples were collected online every 30 minutes for sulfur in the analysis of sulfur content in the liquid phase and also analysis of the gaseous products.

Table 4.3.1 List of the experiments to study the effect of syn-gas composition

Run #	Run ID	Reactor	Objective
29	LGO60COL	Autoclave 1L	To treat LGO under 60% CO and 30%H_2
32	LGO30COL	Autoclave 1L	To treat LGO under 30% CO and 60%H_2
33	LGO100COL	Autoclave 1L	To treat LGO under pure CO
35	LGO100HL	Autoclave 1L	To treat LGO under pure H_2

Table 4.3.2 Common reaction conditions for syn-gas composition runs

Common operating conditions:	
Reaction time	2 hrs
Reaction temperature	400 oC
H_2S loading	10 psi
Total system pressure	600 psi
Feed	300 ml LGO and 30 ml Water
Catalyst	1500 ppm Mo

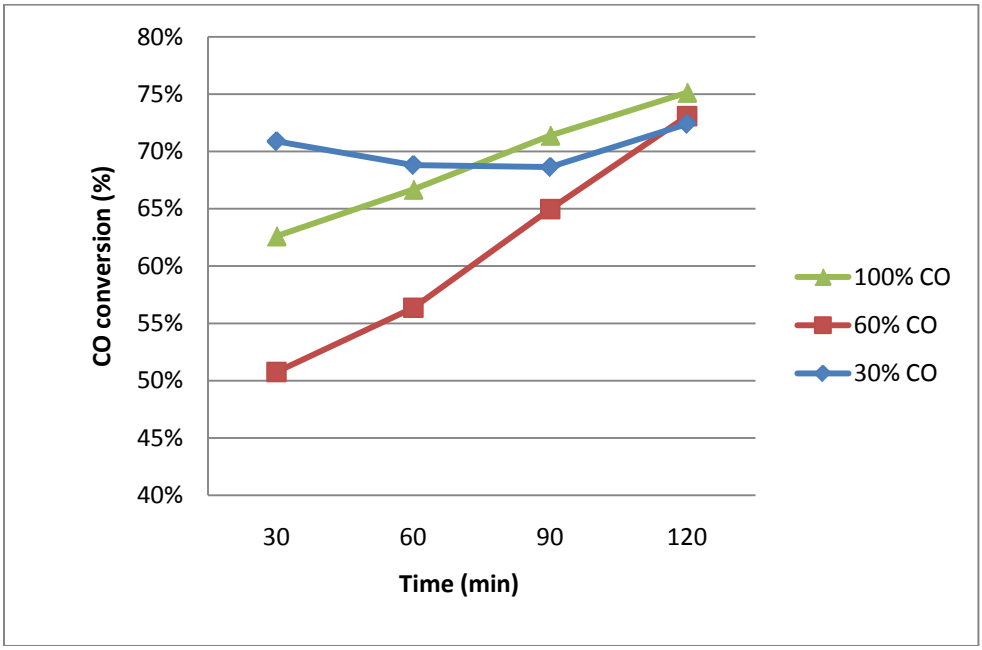


Figure 4.3.1: Effect of Syn-Gas composition on CO Conversion

Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

As shown in the GC analysis for the gas samples (Figure 4.3.), at 30 min, the conversion of CO was 50 % for the experiment starting with 60% CO, while the conversion was 62% for experiment with 100 % CO. Interestingly at 30 min, the conversion of CO was highest for the experiment with 30 % CO .At 120 min, all the three compositions reached the same conversion of about 72%. The apparent rate of conversion of CO was highest for the experiment with 60% CO. The trend observed for the CO conversion is hard to interpret at the moment since one may expect CO conversion for the experiment with 30% CO initial CO loading should be the slowest due to the reversible WGSR. The results also showed gradual increase of H_2S as the percentage of H_2 initially used was increased (Figures 4.3.2). The gas samples represent the dissolved gases in the liquid phase.

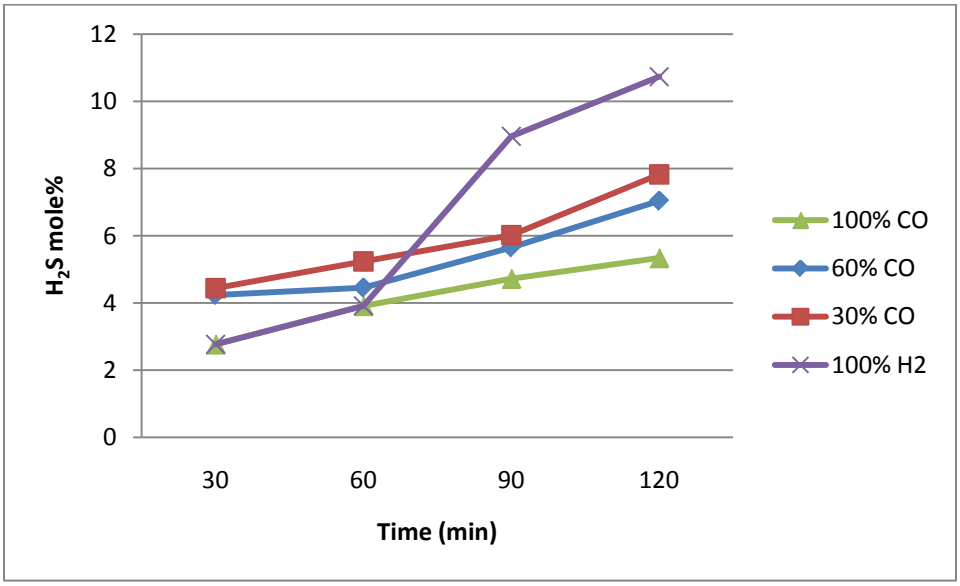


Figure 4.3.2: H_2S in gas phase for syn-gas runs
Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

It is also shown that the amount of H_2 produced in the case of 60% CO was more than the case when 100% CO was initially used (Figures 4.3.3 and 4.3.4). When 30%CO was used, more dissolved H_2 was detected as shown in Figure 4.3.5 which suggest that the amount of H_2 existing in the liquid phase increased with initial H_2 used in the syn-gas. It was also suggested that the amount of H_2 detected by the GC was not representing the actual amount of H_2 existing in the system since the gas samples were collected along with the liquid phase which represents only the dissolved and produced gases . These are preliminary results which need to be confirmed and repeated.

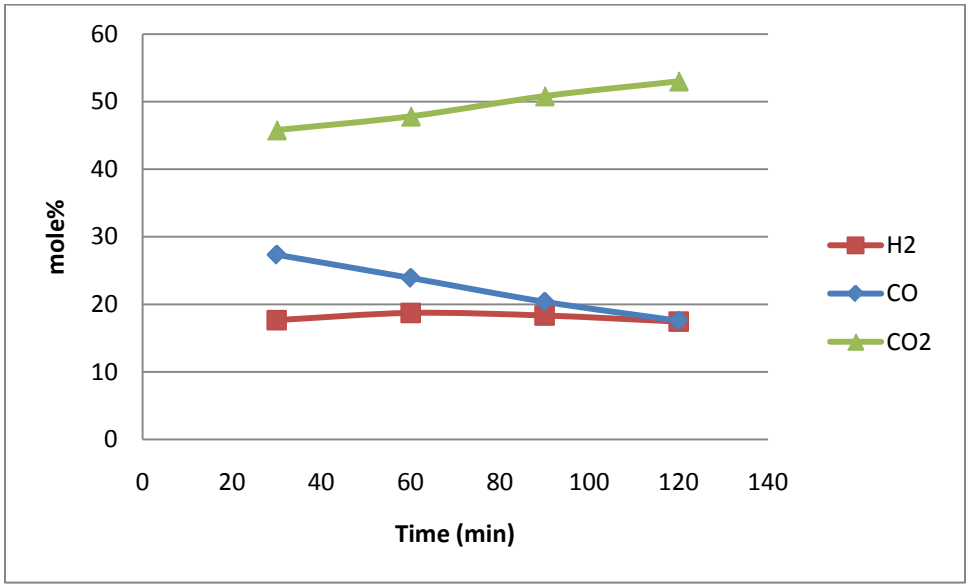


Figure 4.3.3: RGA results for run#33 with initial 100%CO loading Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

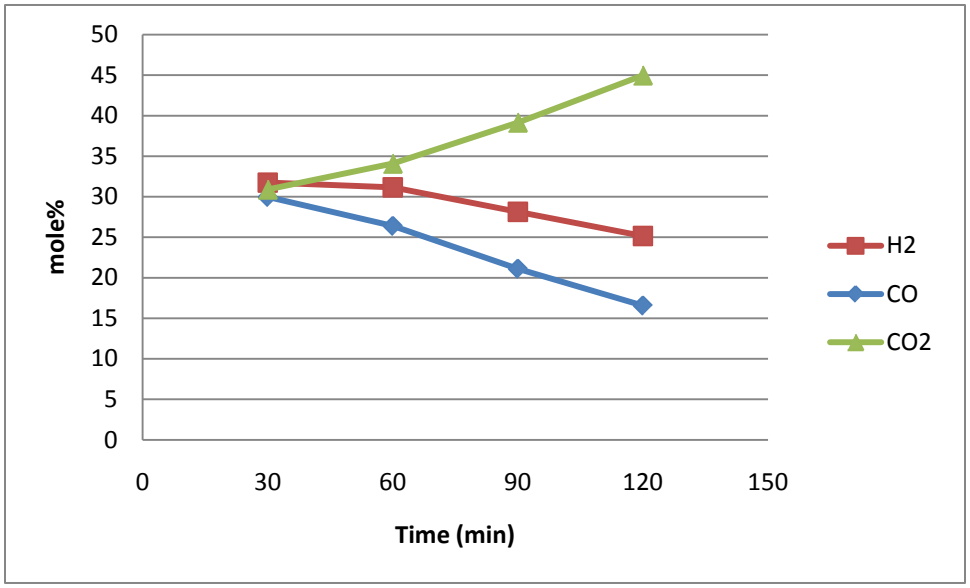


Figure 4.3.4: RGA results for run#29 with initial 60%CO loading Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

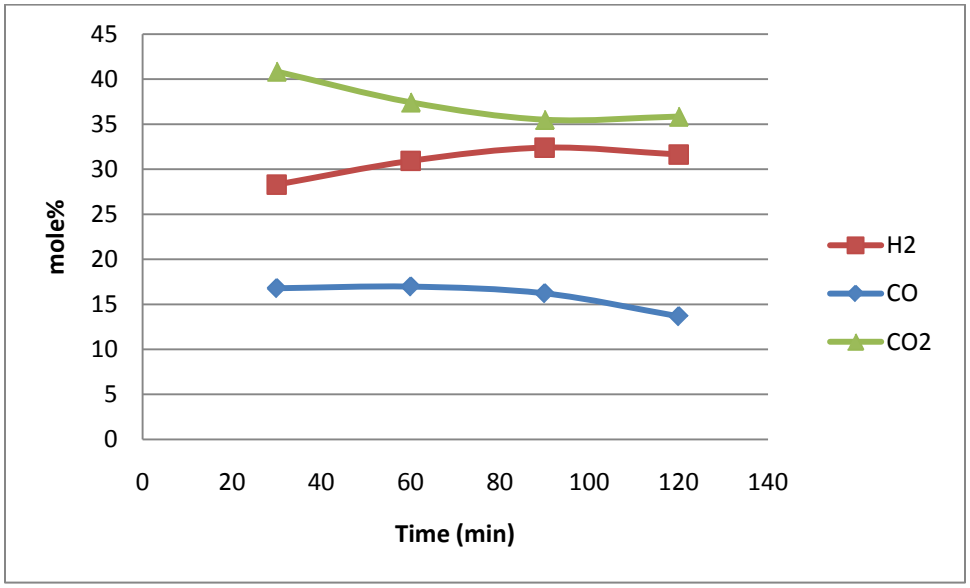


Figure 4.3.5: RGA results for run#32 with initial 30%CO loading

Conditions; 2hr, 400^{o}C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

The XRF results of the sulfur content of each sample were plotted against time to study the rate of the HDS in each case. Figure 4.3.7 shows that the rate of sulfur removal in the case of pure CO (LGO100CO) was the fastest and that the rate slows as the percentage of CO is reduced. It is clear that more sulfur was removed in the early stages when the molecular H_2 used, but molecular H_2 still had the slowest rate. Compared to the pure CO, H_2 shows lower HDS activity in the final 30 minutes, which agrees with the results obtained from batch autoclave experiments (LGOR2 (run#11) and LGOH (run#4) where in-situ H_2 generated from CO was more effective for sulfur removal.

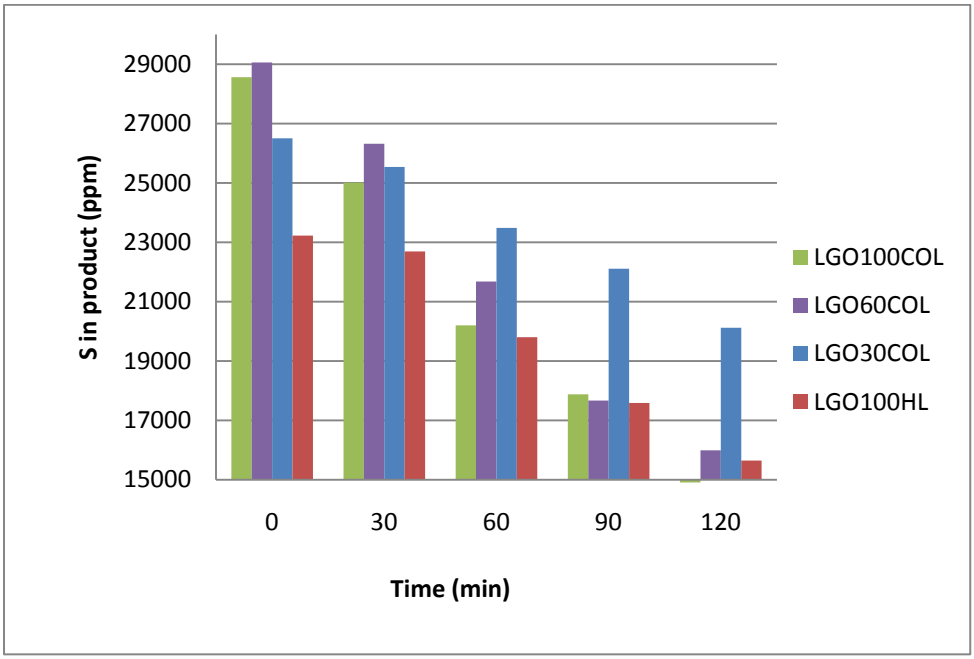


Figure 4.3.7: Effect of time on sulfur content in the product
Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

The PFPD results show that the sulfur compounds found in the case of pure CO is similar to that in the case of pure H_2. The main difference between the two results is the amount of DBT found in the case of pure CO is less than the other one. This could explain the higher activity of the HDS of CO over H_2. Figures 4.3.8 and 4.3.9 show the amount of sulfur compounds exist in the liquid samples in both LGO100COL and LGO100HL runs.

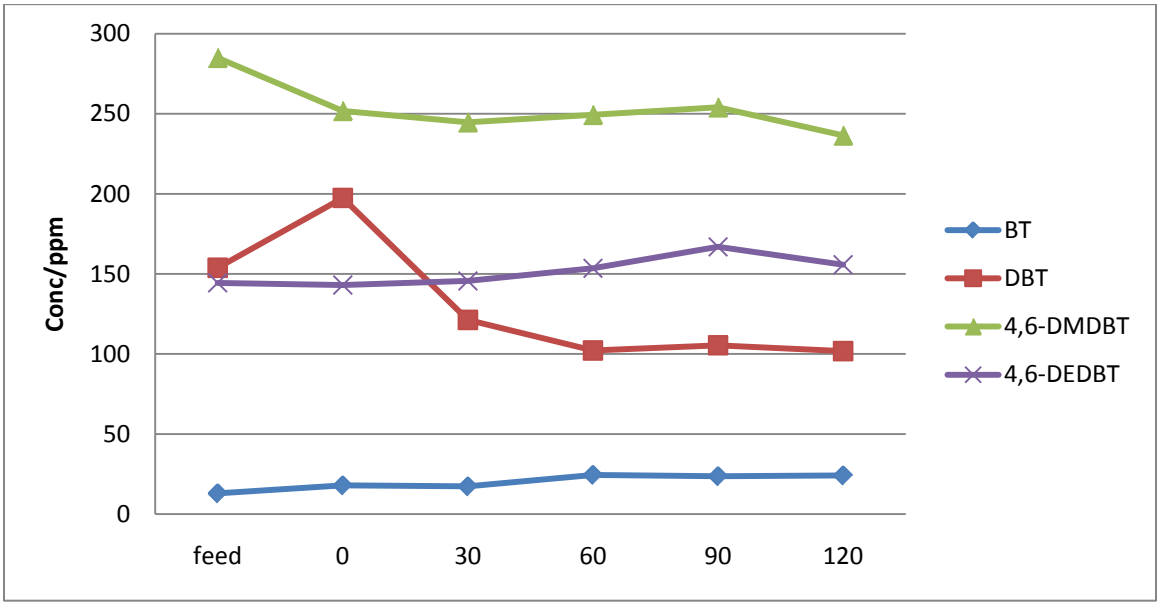


Figure 4.3.7: Sulfur compounds in the product of run#33 with initial 100%CO loading Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

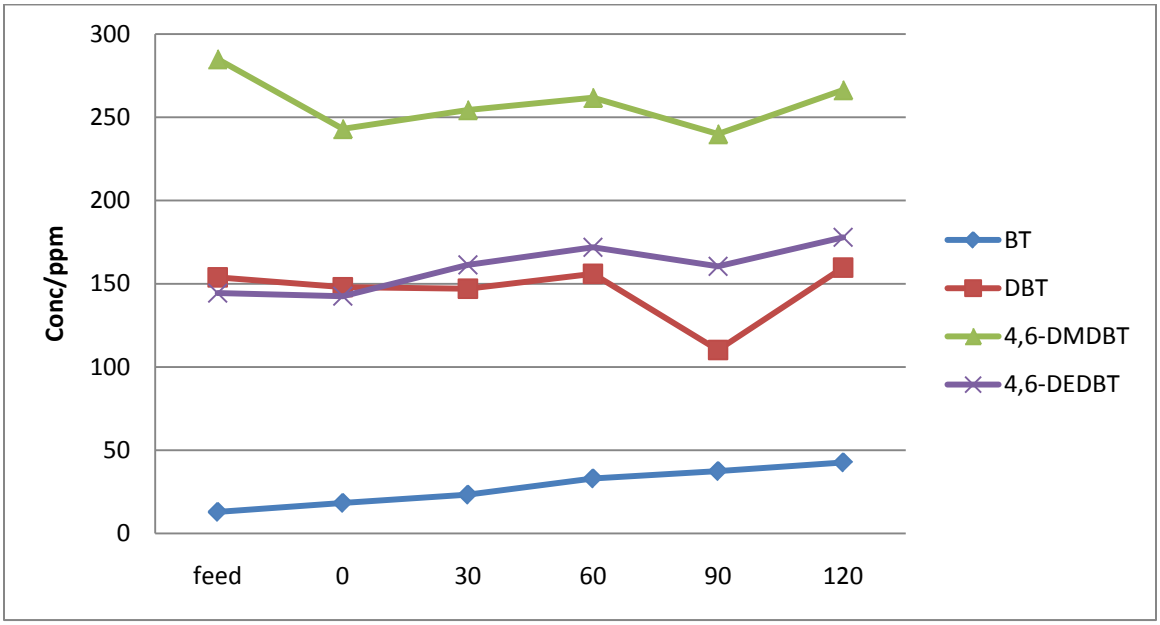


Figure 4.3.7: Sulfur compounds in the product of run#35 with initial 100%H_2 loading Conditions; 2hr, 400°C, 100ml LGO, 10 ml water, and 1500ppm Mo, 1L reactor

4.4 Temperature Effect

Reaction temperature was raised from 391^{o}C to 410^{o}C to study the effect of the temperature on the reaction when it enters the Hydrocracking regime. As shown in Figure 4.4.1, more sulfur was removed when the temperature was raised to 410^{o}C. It was also noticed that H_2 was less in the GC analysis compared to the 391^{o}C reaction which might be consumed in the HDS reaction. Further investigation was carried out using SimDis to study the boiling range in both temperature cases. The SimDis results showed that the volume percent of naphtha cut was improved by 65% when the temperature was increased from 391^{o}C to 410^{o}C while the heavy gas oil fraction decreased and the pitch conversion remained at 80% as shown in Figure 4.4.2.

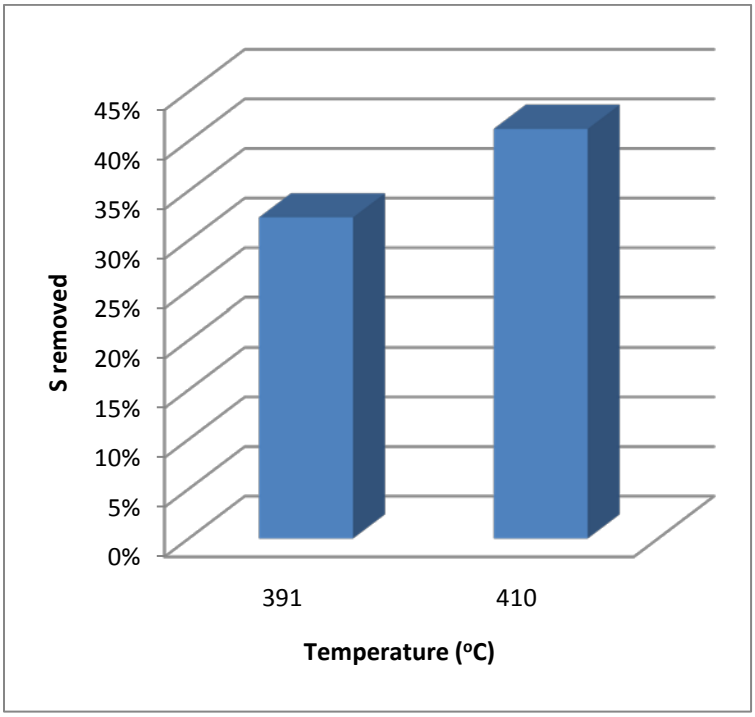


Figure 4.4.1: Effect of temperature on S removal

Conditions; 100 ml LGO, 10 ml water, time 2hs, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo.

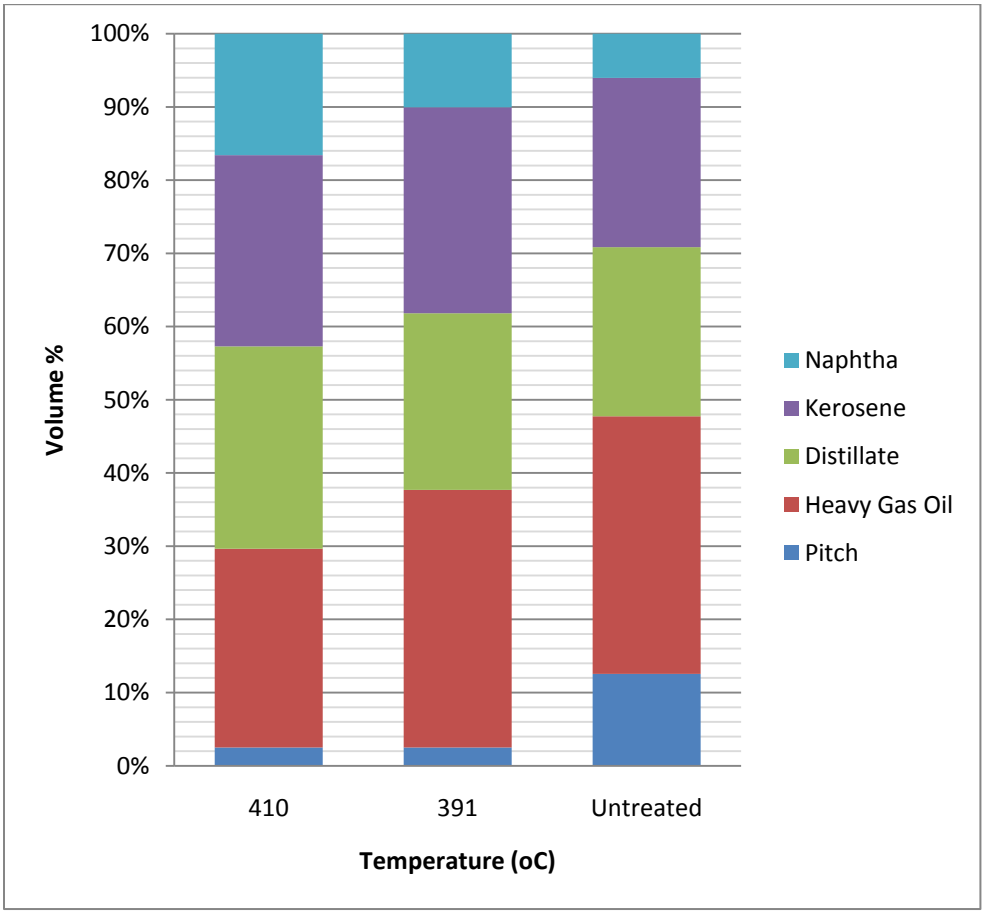


Figure 4.4.2: Boiling point distribution at different reaction temperature

Conditions; 100 ml LGO, 10 ml water, time 2hs, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo.

Boiling point ranges: naphtha (<204 ^oC), kerosene (204-288 ^oC), distillate (288-343 ^oC), heavy gas oil (343-524 ^oC), pitch (>524 ^oC)

4.5 Effect of reaction time

Three experiments were done on different reaction times; half hour, one and three hours in addition to the reference experiment (LGOR2 run#11) which was at 2 hours reaction time. From Figure 4.5.1, it is obvious that the amount of sulfur removed increased with reaction time for the first 2 hours then started to stabilize. The gas analysis for these experiments (Figure 4.5.2) shows similar trend with Figure 4.3.3.

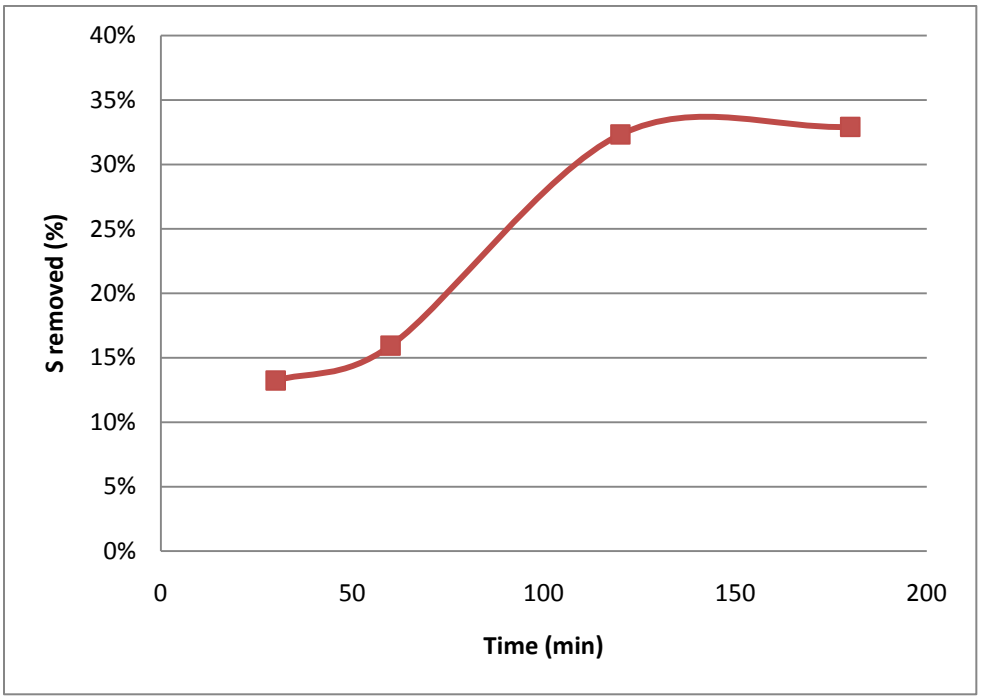


Figure 4.5.1: Effect of reaction time on S removal

Conditions; 100 ml LGO, 10 ml water, 390°C, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo.

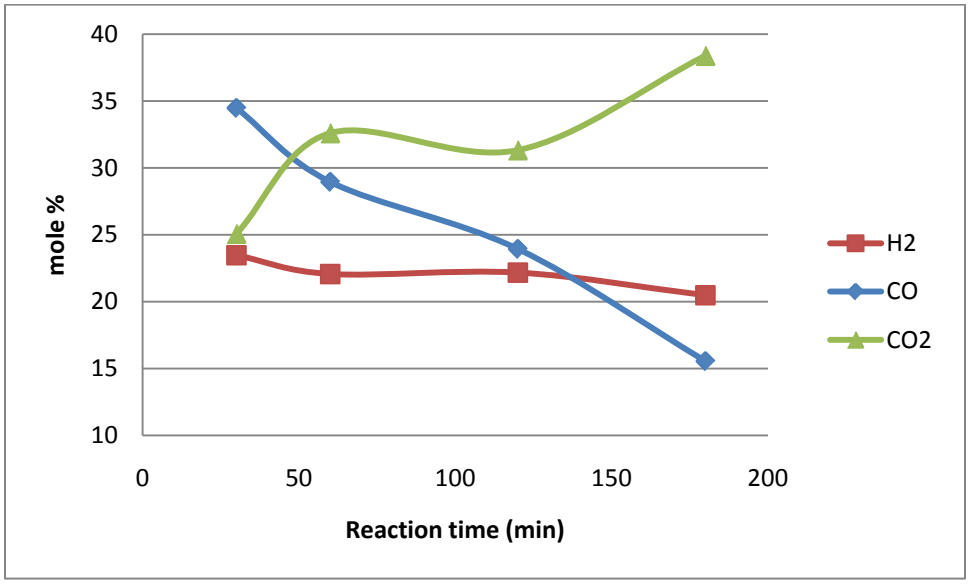


Figure 4.5.2: RGA analysis for different reaction time

Conditions; 100 ml LGO, 10 ml water, 390^{o}C, under 590 psi CO, 10 psi H_2S, 1500 ppm Mo.

Chapter 5
Conclusions and Recommendations

5.1 Conclusions

The results of this study showed that Ni and Co have a promoting effect over un-promoted Mo catalysts for both HDS and WGSR. Ni was found to be the best promoter for both reactions. Fe showed no significant effect for both WGSR and HDS. V and K have a good promoting effect in WGSR but they inhibited the HDS reaction. Potassium was found to be the strongest inhibitor for the HDS reaction where no sulfur was removed during the reaction.

The water and gas medium effect study showed that the effect of water under molecular hydrogen is much less than in case of using CO. It was found that the HDS activity is inversely proportional to the amount of water and the best results was obtained when 5 vol. % of water to LGO used. It was found that molecular H_2 performed better than in-situ H_2 which indicates that when the amount of water exceeds certain value it inhibits the HDS reaction more when CO used than molecular H_2.

Syn-gas showed more HDS activity over the molecular H_2. Syn-gas composition effect study showed that the rate of sulfur removal in the case of pure CO (LGO100CO) is the fastest one and the rate then gets slower as we reduce the percentage of CO. It is clear that more sulfur was removed in the early stages when the molecular H_2 was used but it showed the slowest rate.

5.2 Recommendations

It is recommended to extend this work to study the possibility of the gasification of the residue to produce syn-gas. This also can be extended to use the product syn-gas as a treatment medium.

Also, it is recommended to study the major catalyst decay factors. Catalysts also need to be recycled if possible and the metals involved could be recovered.

It is recommended to conduct catalyst characterization for different syn-gas experiments to study the catalysts properties under different reaction conditions. Kinetic studies on the WGSR and upgrading of bitumen emulsion should be carried out to provide data for the development of a model for upgrading bitumen emulsions.

Syn-gas composition experiments should be conducted to study the composition effect on other reactions such as the hydrogenation and denitrogenation.

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Nomenclature

k’	Rate Constant
m	Mass
M	Molecular Weight
n	Moles
P	Pressure
R	Universal Gas Constant
T	Temperature
V	Volume
WGSR	Water Gas Shift Reaction

Appendices

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Appendix A

List of Experiments

Table A1: List of experiments

Run #	Run ID	Water (ml)	Medium	Time (hr)	Promoter	Temp. (°C)	React. Vol. (ml)
1	**LGOL**	10	CO	2	None	390	300
2	**LGOR**	10	CO	2	None	390	300
3	**LGO5W**	5	CO	2	None	390	300
4	**LGOH**	10	H_2	2	None	390	300
5	**LGOH5W**	5	H_2	2	None	390	300
6	**LGO1HR**	10	CO	1	None	390	300
7	**LGOH5W2**	5	H_2	2	None	390	300
8	**LGONi**	10	CO	2	Ni	390	300
9	**LGOCo**	10	CO	2	Co	390	300
10	**LGOH2**	10	H_2	2	None	390	300
11	**LGOR2**	10	CO	2	None	390	300
12	**LGO30MIN**	10	CO	0.5	None	390	300
13	**LGO3HRS**	10	CO	3	None	390	300
14	**LGOFe**	10	CO	2	Fe	390	300
15	**LGOV**	10	CO	2	V	390	300
16	**LGOR2L**	10	CO	2	None	390	1L
17	**LGO5WL**	10	CO	2	None	390	1L
18	**LGOH15WL**	15	H_2	2	None	390	1L
19	**LGONi2**	10	CO	2	Ni	390	300
20	**LGOV2**	10	CO	2	V	390	300
21	**LGO410T**	10	CO	2	None	410	300
22	**LGOK**	10	CO	2	K	390	300
23	**LGO15W**	15	CO	2	None	390	300
24	**LGOH15W**	15	H_2	2	None	390	300
25	**LGO121**	10	CO/H2	2	None	390	300
26	**LGO30CO**	10	33%CO - 66%H_2	2	None	390	300
27	**LGO60CO**	10	66%CO - 33%H_2	2	None	390	300
28	**LGOR3**	10	CO	2	None	390	300
29	**LGO60COL**	30	66%CO - 33%H_2	2	None	400	1L

Cont.

Run #	Run ID	Water (ml)	Medium	Time (hr)	Promoter	Temp. (^{o}C)	React. Vol. (ml)
30	**LGON**	10	CO	2	None	390	300
31	**LGODN**	10	CO	2	None	390	300
32	**LGO30COL**	30	33%CO - 66%H_2	2	None	400	1L
33	**LGO100COL**	30	CO	2	None	400	1L
34	**LGO2000Mo**	10	CO	2	None	390	300
35	**LGO100HL**	30	H2	2	None	400	1L

Table A2: Reproducibility experiments (run#8 and 19)

	LGONi	LGONi2	%repr.
Date	**29-Oct**	**23-Jan**	
S removal	56.52%	55.64%	1.56%
H_2 mole	16.90178	18.59869	10.04%
CO mole	22.40998	16.12395	28.05%

Table A3: Reproducibility experiments (run#15 and 20)

	LGOV	LGOV2	%repr.
Date	**14-Nov**	**29-Jan**	
S removal	22.61%	23.87%	5.56%
H_2 mole	26.10465	29.68911	13.73%
CO mole	18.69295	23.72311	26.91%

Table A4: Reproducibility experiments (run#4 and 10)

	LGOH	LGOH2	%repr.
Date	**16-Oct**	**3-Nov**	
S removal	23.65%	24.98%	5.64%
H_2 mole	79.482796	84.36137	6.14%

CO mole	0	0	

Table A5: Reproducibility experiments (run#5 and 7)

	LGOH5W	**LGOH5W2**	**%repr.**
Date	**20-Oct**	**27-Oct**	
S removal	22.86%	27.08%	18.46%
H_2 mole	81.08379	83.40349	2.86%
CO mole	0.08081	0.06132	24.12%

Appendix B
Calculations

Mass balance:

Due to the frequent online sample collection in the 1L reactor, complete mass balance was not carried out. For the experiments carried out in the 300ml reactor, overall mass balance was calculated for the liquid phase as follows;

(This sample calculation is carried out based on the data and results of run#8)

mass of feed LGO = 87.5 g

initial water volume = 10 ml

mass of total lquid product= 87.98

volume of product water phase= 3.5 ml

mass of product water phase = 3.5 g

mass of product LGO = 87.98-3.5 = 84.48 g

Total loss of LGO = 87.5 - 84.48 = 3.02g

% of LGO loss = 3.68%

water consumed = 10 - 3.5 = 6.5 ml

More mass balance calculation is listed in Table B1

Table B1: Mass balance calculation

Runs	**LGO5W**	**LGOH**	**LGOH5W**	**LGOH5W2**	**LGONi**
Cat. Amount (ppm) of tot Org. mass	1500	1500	1500	1500	1500
LGO volume (ml)	100	100	100	100	100
Weight of LGO + Graduated cylinder (g)	343.55	344.13	344	343.5	344.12
Weight of empty cylinder (g)	256.3	257.47	255.93	256.75	256.62
Mass of LGO (g)	87.25	86.66	88.07	86.75	87.5
Mass of catalysts (PMA) needed (g)	0.2075	0.2061	0.2094	0.2063	0.2081
Water solution volume (ml)	5.00	9.90	4.90	4.90	9.79
Total mass of the feed (g)	96.31	105.58	96.93	96.61	97.42
P H2S (psi)	10	10	10	10	10
P CO (psi)	590	590	590	590	590
Total system pressure (psi)	600	600	600	600	600
Maximum pressure (psi)	1552	1824	1543	1450	2150
Reaction Temp (^{o}C)	392	392	392	391	391
Reaction Time (hrs)	2	2	2	2	2
Final Pressure (psi)	339	313	384	373	523
Liquid Product volume (ml)	93	102	104	99	100
Water phase volume (ml)	0.75	8	4	2	3.5
Wieght the liquid product+Liner (g)	86.32	90.54	88.66	87.14	87.98
Weight of the Liner after Rxn (g)	0	0	0	0	0
Mass balance					
Total Mass of Liquid product (g)	86.32	90.54	88.66	87.14	87.98
Water volume (in product) %	0.81%	7.84%	3.85%	2.02%	3.50%
Total Input (g)	87.46	86.87	88.28	86.96	87.71
Total Output (g)	85.57	82.54	84.66	85.14	84.48
% Losses	2.16%	4.98%	4.10%	2.09%	3.68%
Water consumed (ml)	4.25	1.90	0.90	2.90	6.29

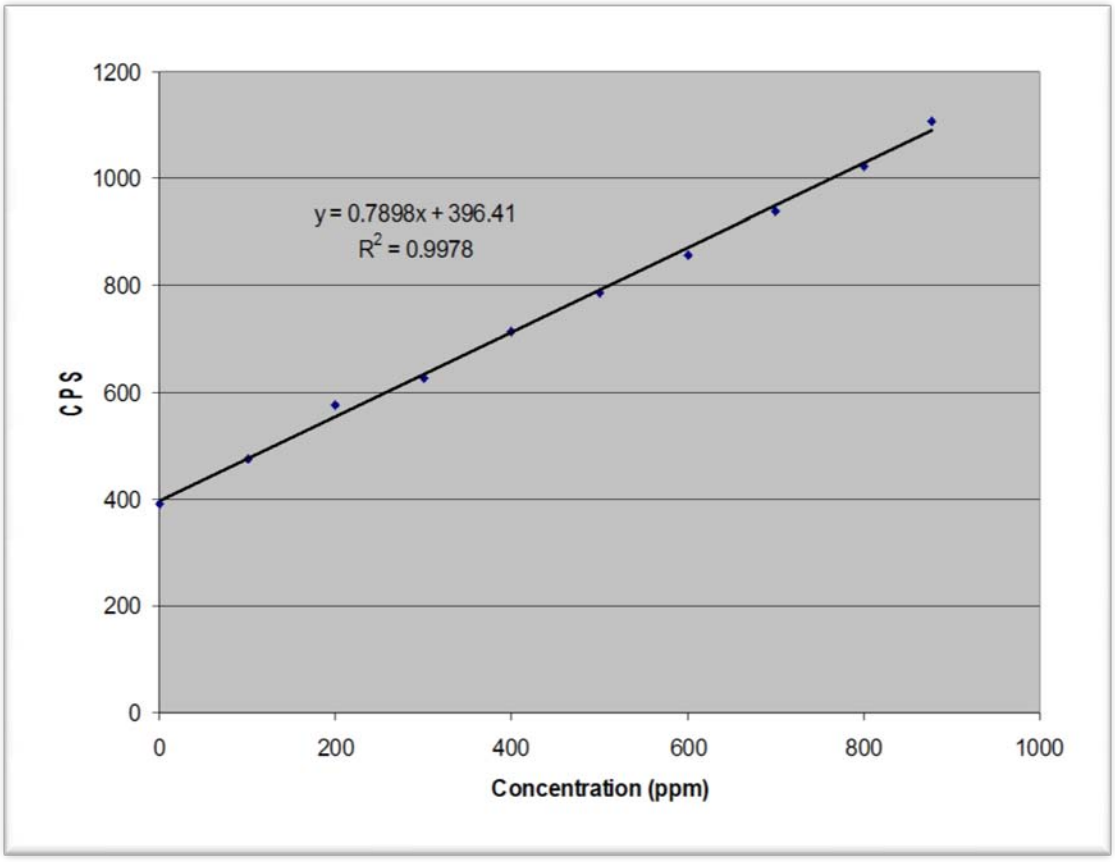


Figure B1: XRF calibration curve

CO conversion:

This smple calculation is carried out based on the data and results of Run#11:

Assuming Ideal Gas Law

Initial Reading for CO loading:

Temperature = 25 ^{o}C =298 K

Pressure = 590 psi = 40.14714 atm

Liquid Volume = 110 ml = 0.11 L

Working Volume = 249 ml = 0.249 L

Gas feed Volume = 249 – 110 = 139 ml = 0.139 L

Initial moles of CO (N_i) = 0.22820037 (from the ideal gas law)

Gas product reading:

Temperature = 25 ^{o}C =298 K

Pressure = 353 psi = 24.02024 atm

Liquid Volume = 97 ml = 0.97 L

Working Volume = 249 ml = 0.249 L

Gas feed Volume = 249 – 97 = 152 ml = 0.152 L

Final moles of CO (N_f) = 0.14930276 (from the ideal gas law)

CO conversion $X_{CO} = N_{COi}-N_{COf}/N_{COi}$ = 81.08%

Table B2: GC analysis (run#11)

	Mol%	Norm.Mol%
H2	22.59853	26.50311772
CH4	1.5309	1.795409831
CO	24.66369	28.92509732
CO2	33.46837	39.25105527
C2H6	0.54884	0.643668908
H2S	1.85406	2.174405611
COS	0.0829	0.097223512
Heavier	0.52015	0.610021832

Appendix C

Raw Data

Table C1: Operating parameters for run# 3

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	1552	388	392	892
15	1530	388	392	888
30	1506	388	392	884
45	1491	388	392	890
60	1475	388	392	891
75	1454	388	392	887
90	1435	388	392	890
105	1419	388	392	888
120	1400	388	392	891

Table C2: Operating parameters for run# 7

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	1414	387	391	890
15	1412	387	391	882
30	1436	387	392	888
45	1450	387	392	888
60	1449	387	392	887
75	1443	387	392	890
90	1435	387	392	890
105	1424	387	392	900
120	1410	387	392	891

Table C3: Operating parameters for run# 9

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2156	390	390	888
15	2166	388	391	890
30	2149	388	391	887
45	2128	388	391	893
60	2102	388	391	902
75	2071	388	391	891
90	2046	388	391	897
105	2015	388	391	895
120	1994	388	391	895
OVERNIGHT	455	psi		

Liquid Product =	96	ml total
Water volume =	3	ml

Table C4: Operating parameters for run# 10

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	1964	388	390	890
15	2003	388	391	888
30	2025	388	391	884
45	2014	388	391	890
60	1988	388	391	891
75	1970	388	391	888
90	1953	388	391	890
105				
120	1924	388.3	391	880
OVERNIGHT	353	psi		

Liquid Product =	100	ml total
Water volume =	5.5	ml

Table C5: Operating parameters for run# 11

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2138	391.3	390	880
15	2206	389.8	392	890
30	2209	388.5	392	899
45	2203	388	392	890
60	2194	387.7	392	892
75	2180	387.8	392	893
90	2164	387.5	392	880
105	2146	387.6	392	888
120	2132	387.7	392	888
OVERNIGHT	611	psi		
Liquid Product =	97	ml total		
Water volume =	3.5	ml		

Table C6: Operating parameters for run# 12

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2141	391	391	891
10	2199	390	393	890
20	2209	389.3	393	890
30	2206	387.6	391	897
OVERNIGHT	624	psi		
Liquid Product =	95	ml total		
Water volume =	6	ml		

Table C7: Operating parameters for run# 13

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	1960	391	392	890
15	2008	389.5	392	888
30	2023	388.2	393	892
45	2021	387.7	392	899
60	2015	387.7	393	899
75	2006	387.5	392	898
90	1994	387.3	392	896
105	1978	387.3	392	896
120	1967	387	392	896
135	1952	387.4	392	890
150	1940	387.3	392	890
165	1926	387.6	392	900
180	1914	387.4	392	900
OVERNIGHT	504	psi		
Liquid Product =	90	ml total		Water volume= 4ml

Table C8: Operating parameters for run# 14

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2160	391.1	391	890
15	2212	390	391	889
30	2230	388.5	391	887
45	2226	388.5	391	888
60	2219	388.1	391	899
75	2210	388.2	391	893
90	2202	388.6	392	895
105	2189	388.7	392	892
120	2178	388.3	392	896
OVERNIGHT	666	psi		

Liquid Product =	95	ml total
Water volume =	0	ml

Table C9: Operating parameters for run# 19

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2177	391.8	390	884
15	2181	390.7	392	890
30	2143	389.5	392	890
45	2086	389	392	893
60	2043	389	392	888
75	2015	388.9	392	899
90	1996	388.9	392	890
105	1963	389	392	890
120	1937	388.6	392	886
OVERNIGHT	532	psi		

Liquid Product =	88	ml total
Water volume =	2.5	ml

Table C10: Operating parameters for run# 20

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	1979	389	390	884
15	1990	389.4	392	895
30	1990	389	392	890
45	1963	389	392	890
60	1947	389	392	896
75	1939	388	392	899
90	1928	388	392	899
105	1915	388	392	900
120	1904	388.7	392	900
OVERNIGHT	559	psi		

Liquid Product =	99	ml total
Water volume =	1.5	ml

Table C11: Operating parameters for run# 21

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2221	409	410	892
15	2209	410	412	890
30	2185	408	411	892
45	2176	407	410	888
60	2160	407	410	888
75	2144	406	409	890
90	2129	405	409	884
105	2105	402	405	880
120	2124	408	411	900
OVERNIGHT	567	psi		

Liquid Product =	98.5	ml total
Water volume =	4.5	ml

Table C12: Operating parameters for run# 22

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	1967	388	390	890
15	1970	388	391	888
30	1947	389	392	888
45	1924	389	392	886
60	1987	389	392	894
75				
90	1852	389	392	890
105	1826	389	392	890
120				
OVERNIGHT		psi		

Liquid Product =		ml total
Water volume =		ml

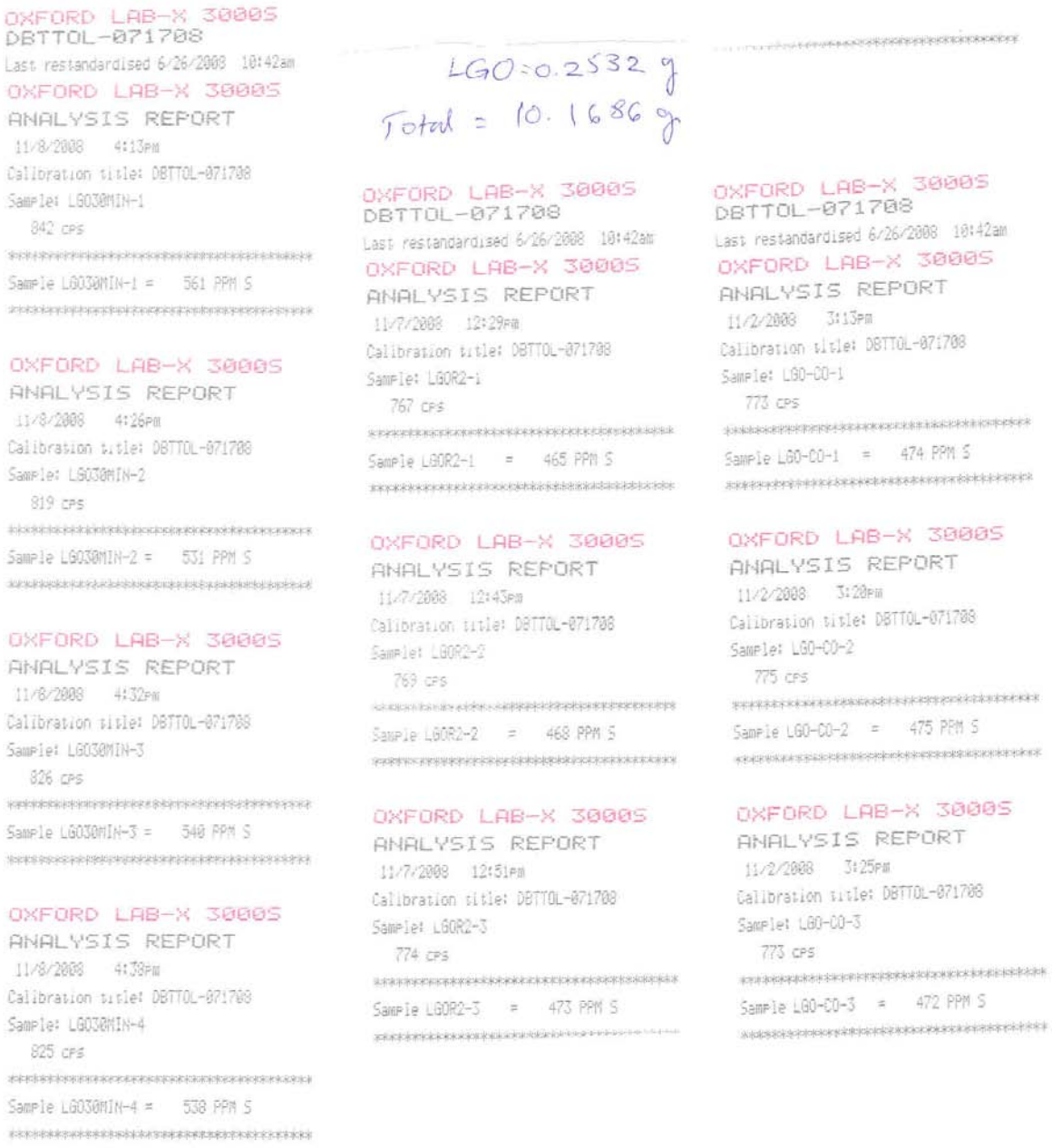
Table C13: Operating parameters for run# 23

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2325	388	390	900
15				
30	2292	389	391	890
45	2245	389	392	898
60	2198	389	392	900
75	2180	389	392	890
90				
105				
120	2066	389	392	890
OVERNIGHT	457	psi		

Liquid Product =	98	ml total
Water volume =	8	ml

Table C14: Operating parameters for run# 24

Time (min)	P (psi)	T(oven) oC	T (react.) oC	rpm
0	2460	389.6	392	890
15				
30	2426	389	392	896
45	2390	389	392	890
60	2375	389	392	898
75	2355	389	392	898
90	2339	389	392	896
105	2325	389	392	902
120	2312	389	392	890
OVERNIGHT	407	psi		
Liquid Product =	109	ml total		
Water volume =	10	ml		



FigureC1: XRF results for runs 12, 11, and 9

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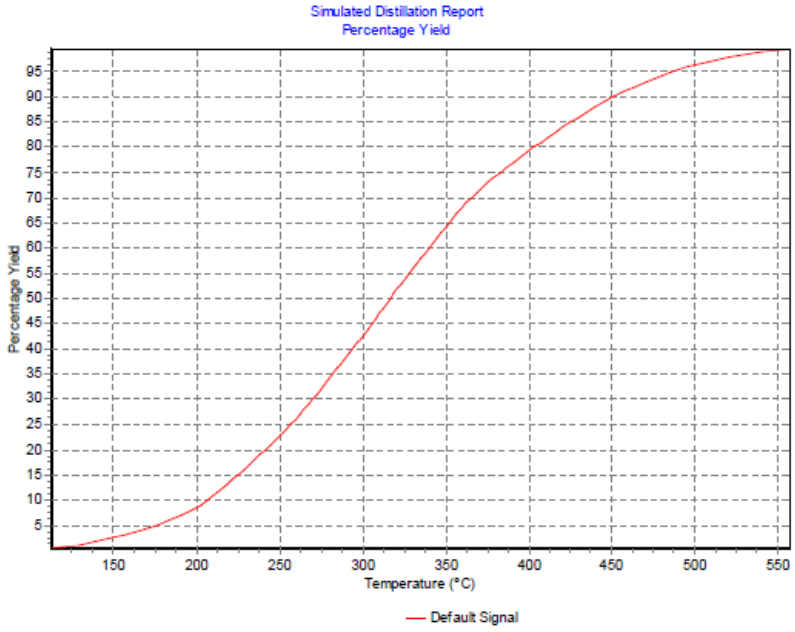

Percentage Yield Table

	Default Signal Temp. (Deg. C)
IBP: 0.5%	112.00
5.00%	176.00
10.00%	206.00
15.00%	225.00
20.00%	241.00
25.00%	256.00
30.00%	270.00
35.00%	282.00
40.00%	294.00
45.00%	306.00
50.00%	316.00
55.00%	328.00
60.00%	339.00
65.00%	352.00
70.00%	365.00
75.00%	383.00
80.00%	403.00
85.00%	425.00
90.00%	451.00
95.00%	487.00
FBP: 99.5%	557.00

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Agilent Technologies

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Figure C2: SimDis result for run# 9

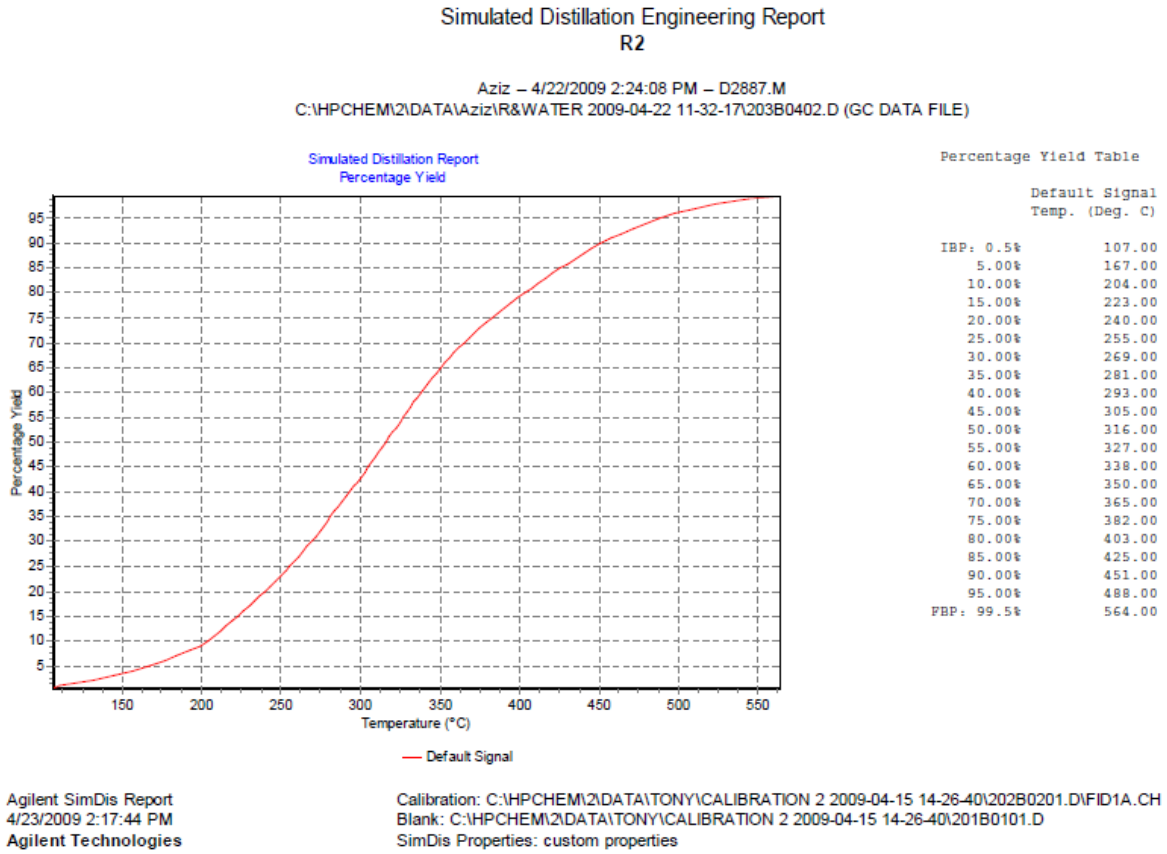

Figure C3: SimDis result for run# 11

Simulated Distillation Engineering Report
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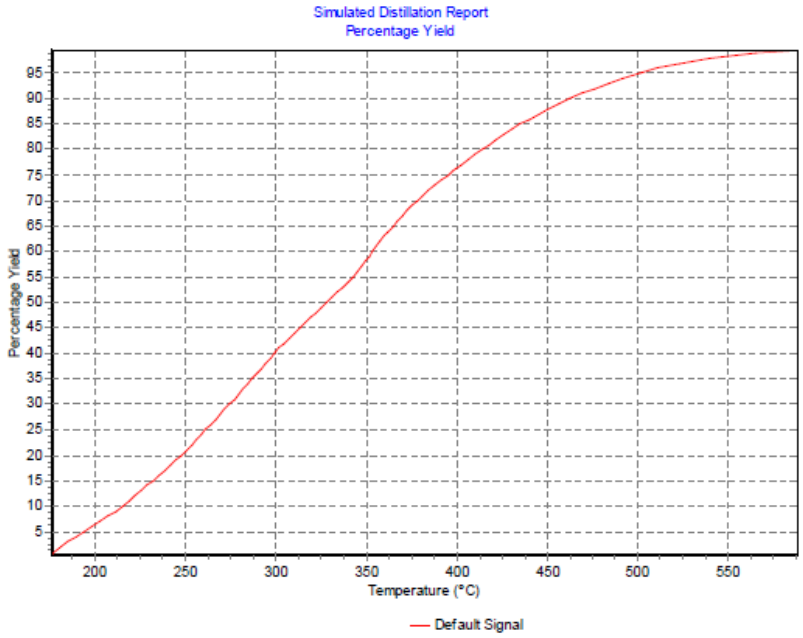

Percentage Yield Table

	Default Signal Temp. (Deg. C)
IBP: 0.5%	176.00
5.00%	194.00
10.00%	215.00
15.00%	232.00
20.00%	248.00
25.00%	261.00
30.00%	274.00
35.00%	287.00
40.00%	299.00
45.00%	313.00
50.00%	328.00
55.00%	343.00
60.00%	353.00
65.00%	365.00
70.00%	378.00
75.00%	395.00
80.00%	414.00
85.00%	435.00
90.00%	462.00
95.00%	501.00
FBP: 99.5%	588.00

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SimDis Properties: custom properties

Figure C4: SimDis result for run# 14

Simulated Distillation Engineering Report

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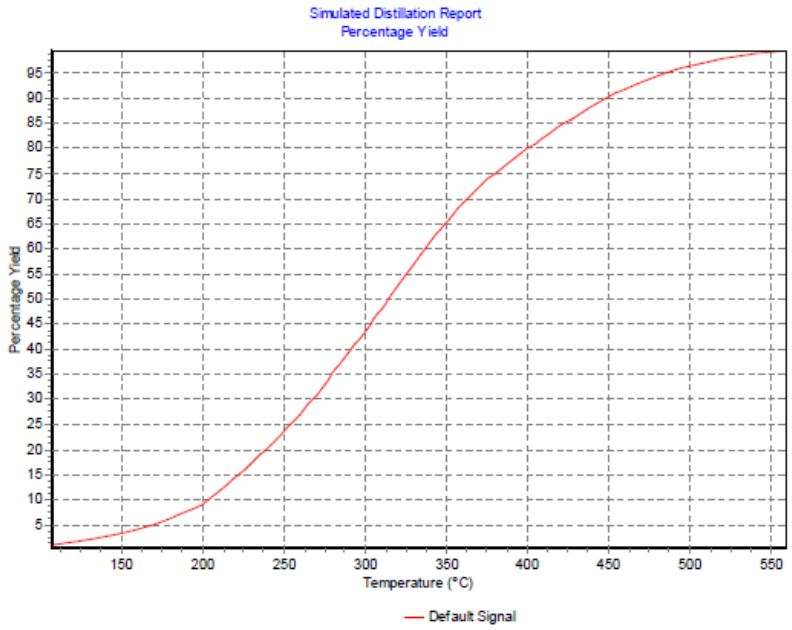

Percentage Yield Table

	Default Signal Temp. (Deg. C)
IBP: 0.5%	107.00
5.00%	169.00
10.00%	203.00
15.00%	222.00
20.00%	239.00
25.00%	254.00
30.00%	267.00
35.00%	279.00
40.00%	291.00
45.00%	303.00
50.00%	314.00
55.00%	325.00
60.00%	337.00
65.00%	349.00
70.00%	363.00
75.00%	379.00
80.00%	400.00
85.00%	422.00
90.00%	448.00
95.00%	484.00
FBP: 99.5%	559.00

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SimDis Properties: custom properties

Figure C5: SimDis result for run# 19

Simulated Distillation Engineering Report
V2

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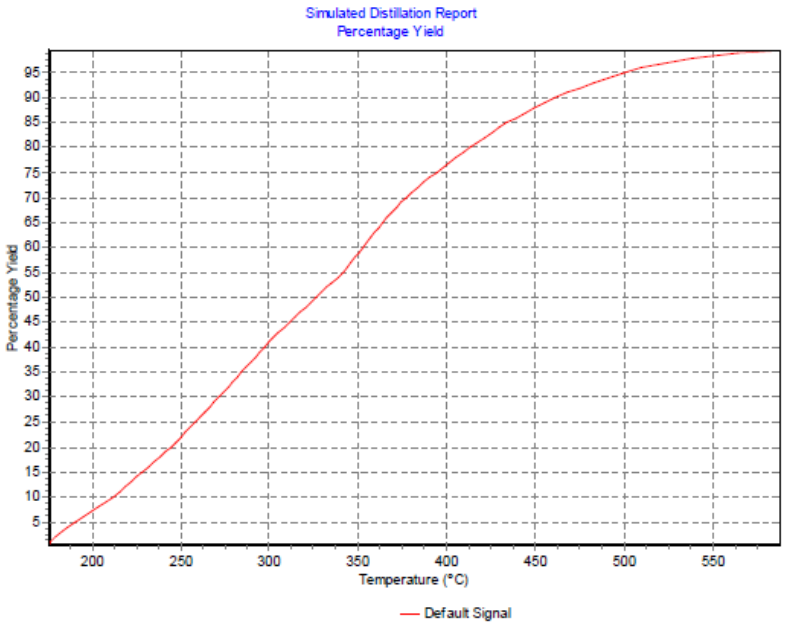

Percentage Yield Table

	Default Signal Temp. (Deg. C)
IBP: 0.5%	176.00
5.00%	191.00
10.00%	212.00
15.00%	229.00
20.00%	244.00
25.00%	258.00
30.00%	271.00
35.00%	285.00
40.00%	297.00
45.00%	311.00
50.00%	326.00
55.00%	341.00
60.00%	352.00
65.00%	364.00
70.00%	377.00
75.00%	394.00
80.00%	413.00
85.00%	434.00
90.00%	461.00
95.00%	500.00
FBP: 99.5%	588.00

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SimDis Properties: custom properties

Figure C6: SimDis result for run# 20

Simulated Distillation Engineering Report
410

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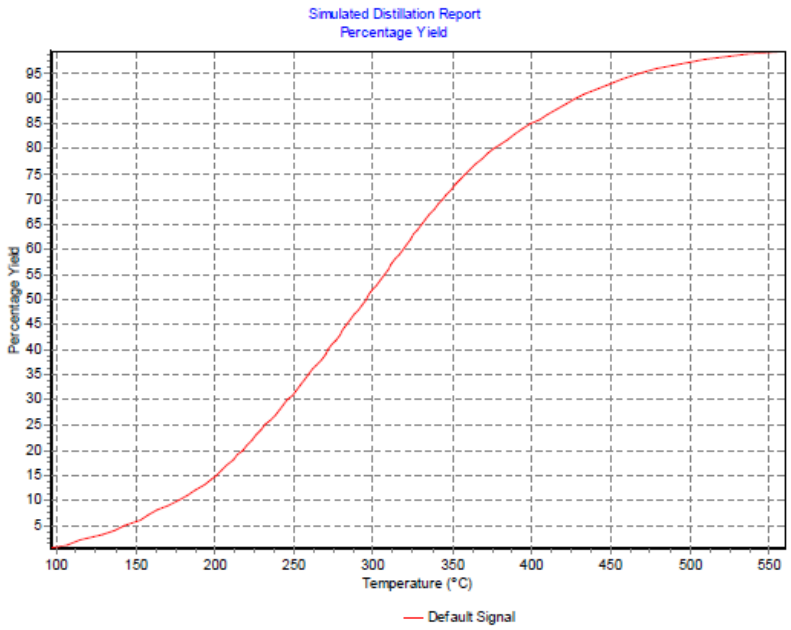

Percentage Yield Table

	Default Signal Temp. (Deg. C)
IBP: 0.5%	97.00
5.00%	143.00
10.00%	177.00
15.00%	201.00
20.00%	217.00
25.00%	232.00
30.00%	246.00
35.00%	259.00
40.00%	272.00
45.00%	283.00
50.00%	295.00
55.00%	307.00
60.00%	318.00
65.00%	331.00
70.00%	344.00
75.00%	358.00
80.00%	376.00
85.00%	399.00
90.00%	427.00
95.00%	467.00
FBP: 99.5%	560.00

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SimDis Properties: custom properties

Figure C7: SimDis result for run# 21

Simulated Distillation Engineering Report
K

Aziz – 4/20/2009 5:18:12 PM – D2887.M
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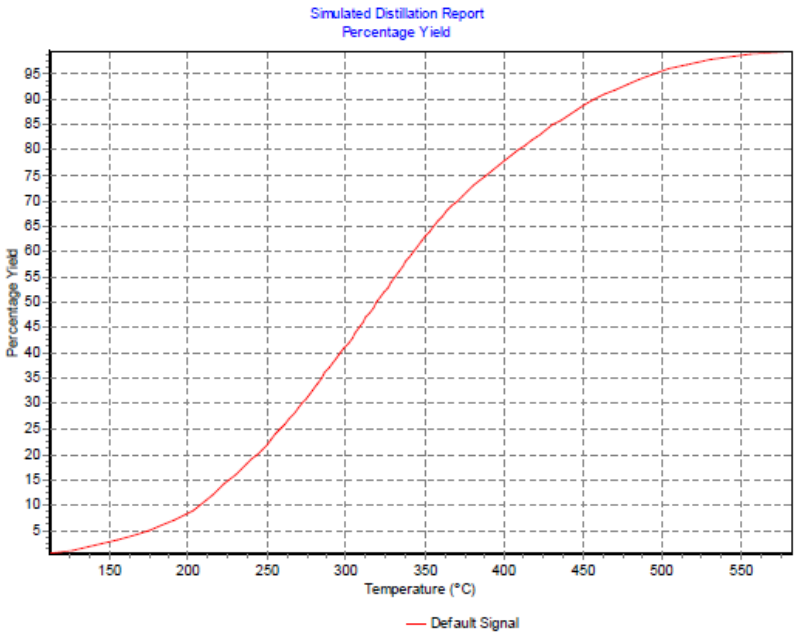


Percentage Yield Table

	Default Signal Temp. (Deg. C)
IBP: 0.5%	112.00
5.00%	175.00
10.00%	207.00
15.00%	226.00
20.00%	243.00
25.00%	259.00
30.00%	272.00
35.00%	284.00
40.00%	297.00
45.00%	308.00
50.00%	319.00
55.00%	331.00
60.00%	343.00
65.00%	355.00
70.00%	370.00
75.00%	388.00
80.00%	409.00
85.00%	431.00
90.00%	457.00
95.00%	495.00
FBP: 99.5%	582.00

Agilent SimDis Report
4/23/2009 1:57:40 PM
Agilent Technologies

Calibration: C:\HPCHEM\2\DATA\TONY\CALIBRATION 2 2009-04-15 14-26-40\202B0201.D\FID1A.CH
Blank: C:\HPCHEM\2\DATA\TONY\CALIBRATION 2 2009-04-15 14-26-40\201B0101.D
SimDis Properties: custom properties

Figure C8: SimDis result for run# 22

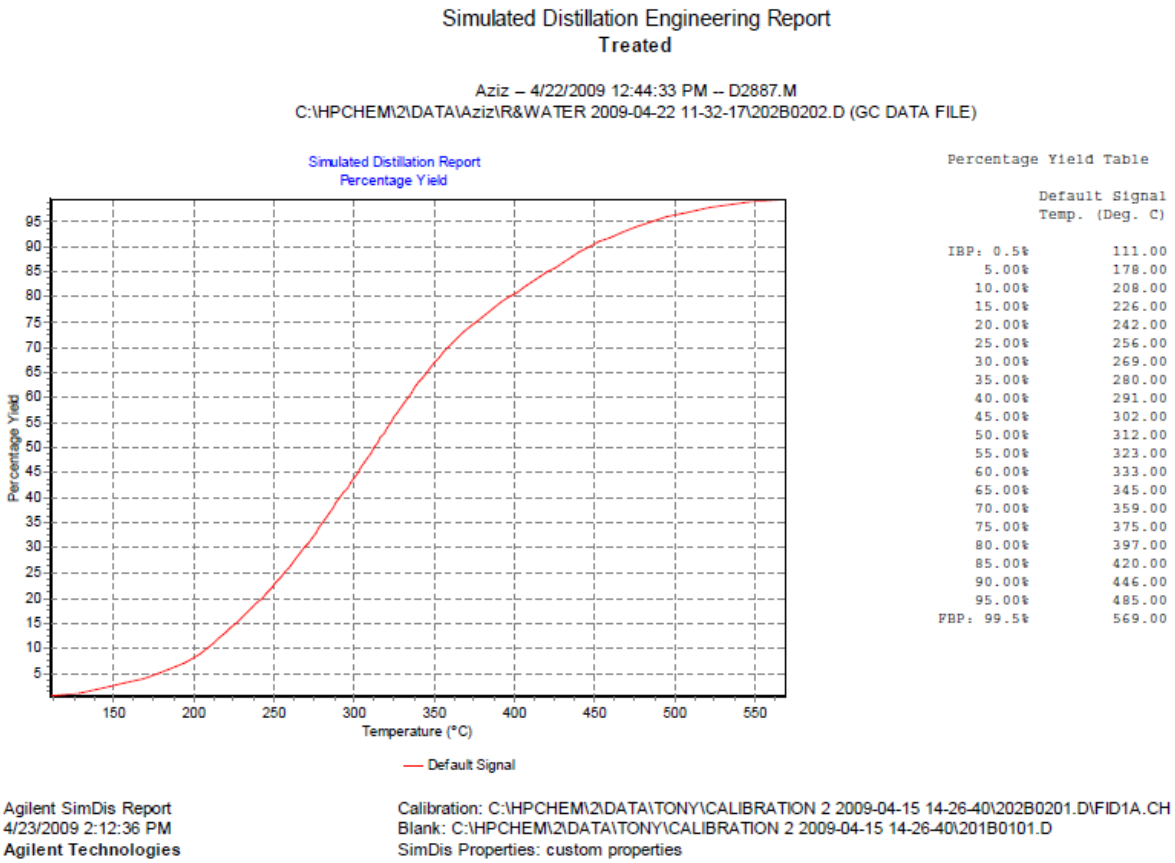


Figure C9: SimDis result for treated LGO in plant

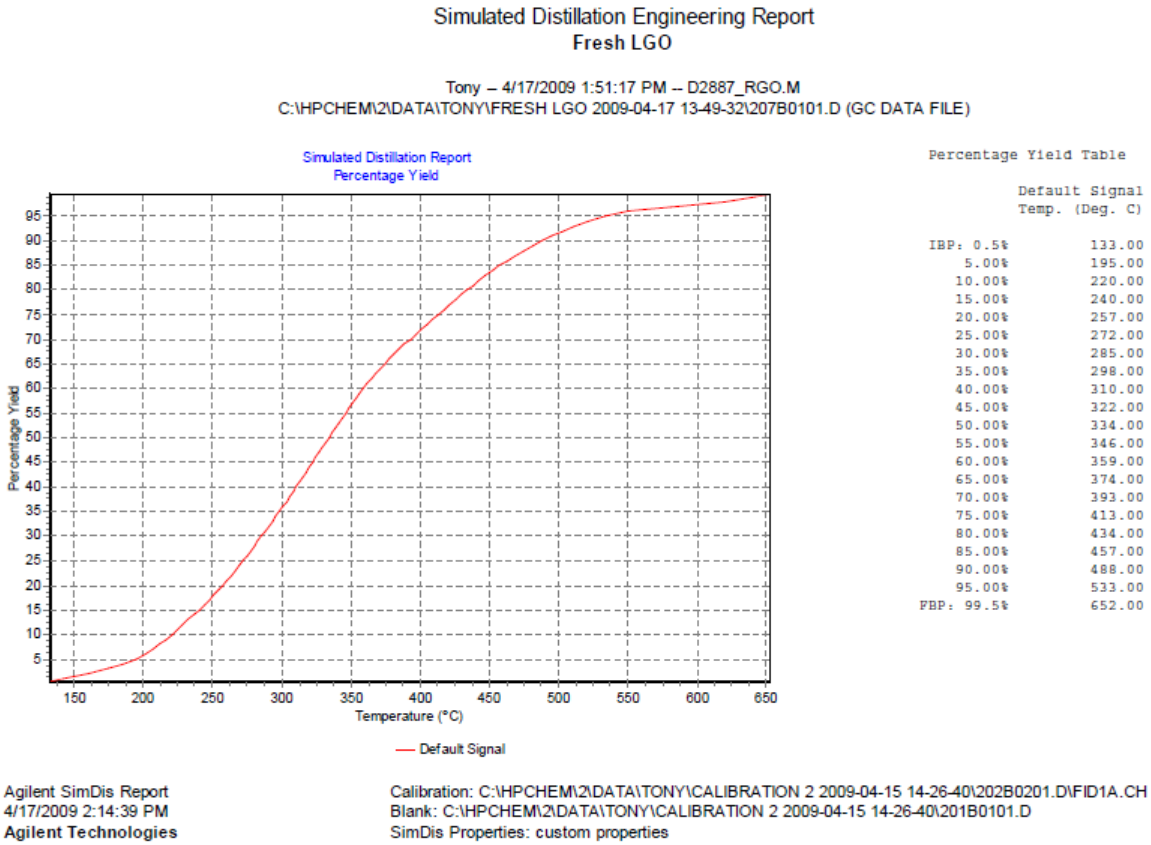


Figure C10: SimDis analysis for untreated LGO sample

Gas analysis reports

RGA report for run# 9

RGA report for run# 10

RGA report for run# 11

RGA report for run# 12

RGA report for run# 13

RGA report for run# 14

RGA report for run# 19

RGA report for run# 20

RGA report for run# 21

RGA report for run# 23

RGA report for run# 29

RGA report for run# 32

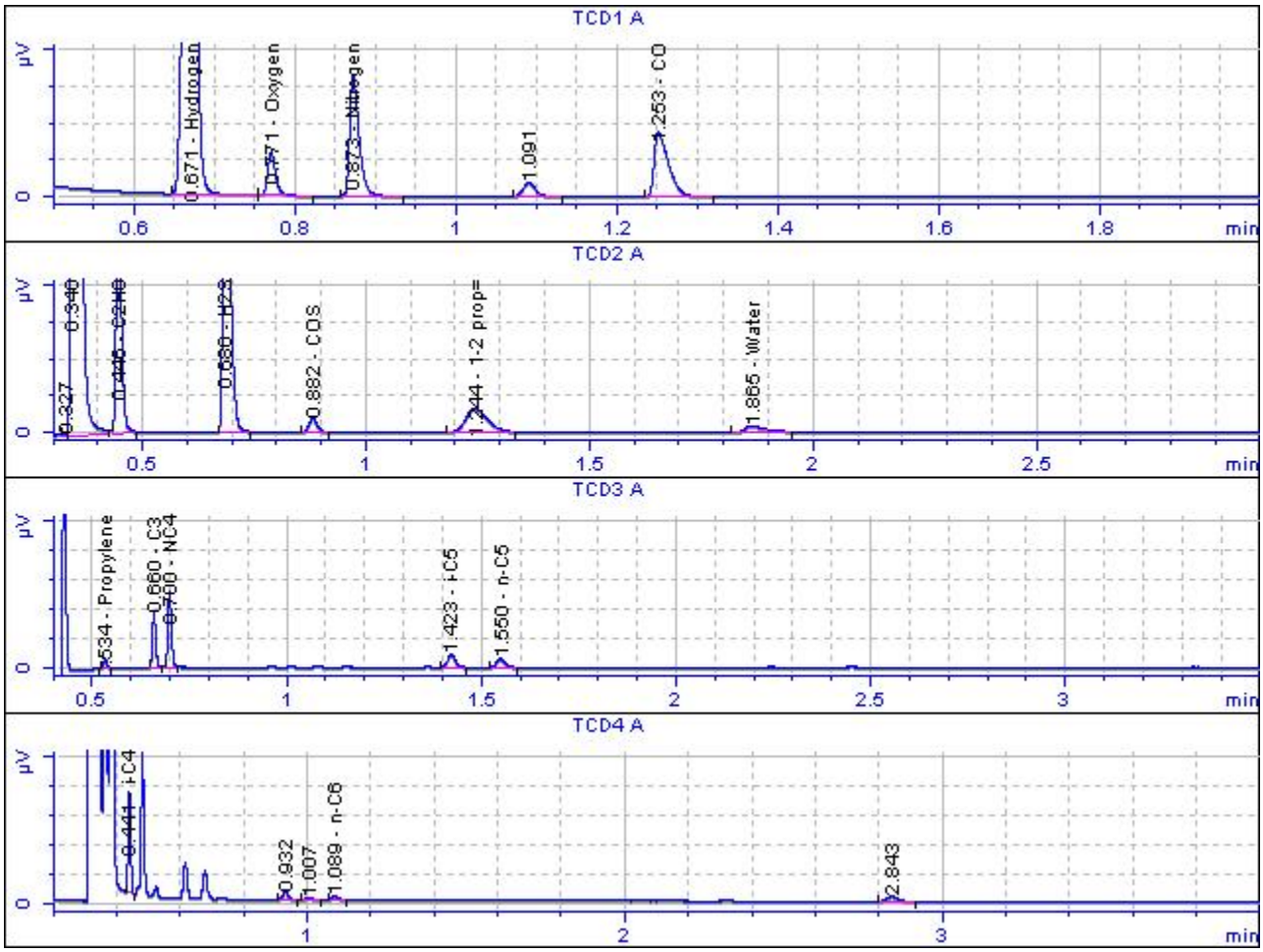
RGA report for run# 33

RGA report for run# 34

RGA report for run# 35

Agilent Cerity QA/QC Report

Sample name:	LGOCo-3
Sample note:	LGO with Co promoter (0.6) final P=455psi @24oC, Oct.31, 2008,
Submission time:	Sunday, November 02, 2008 11:31:44 AM
Operator:	Aziz
Injection date:	Sunday, November 02, 2008 11:42:53 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Saturday, November 01, 2008 2:49:37 PM



Norm Percent Report

Calibration last saved:	Saturday, November 01, 2008 2:49:36 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.671	BP	1.3424e+005	1.07247e-004	25.111583	Hydrogen
1	0.771	VB	4169.85936	1.05820e-003	7.696575	Oxygen
1	0.873	BB	1.3500e+004	1.24916e-003	29.414179	Nitrogen
1	1.064		-	-	-	CH4
1	1.091	BB	2055.27612	0.00000e+000	0.000000	
1	1.253	BB	1.0943e+004	1.28396e-003	24.506867	CO
2	0.327	BP	165.77019	0.00000e+000	0.000000	
2	0.340	VB	5.4945e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.446	BB	2.6732e+004	7.07067e-005	3.296824	C2H6
2	0.548		-	-	-	C2H2
2	0.686	BB	5.4650e+004	7.69512e-005	7.335232	H2S
2	0.882	BB	2529.13643	6.12584e-005	0.270237	COS
2	1.244	PB	1.1076e+004	6.31895e-005	1.220744	1-2 prop=
2	1.865	PB	2653.43735	5.39101e-005	0.249509	Water
2	2.064		-	-	-	MetyAcetylene
3	0.534	BB	191.55485	1.06494e-004	0.035582	Propylene
3	0.660	BB	1149.76713	1.19217e-004	0.239087	C3
3	0.700	BB	1686.05138	8.80082e-005	0.258822	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.423	BB	572.55123	8.46897e-005	0.084577	i-C5
3	1.550	BB	449.91141	8.37984e-005	0.065761	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	3977.73896	2.88341e-005	0.200055	i-C4

4	0.932	BP	707.29593	0.00000e+000	0.000000	
4	1.007	BP	227.65348	0.00000e+000	0.000000	
4	1.089	BB	354.72941	2.32173e-005	0.014365	n-C6
4	2.843	PP	746.90944	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Saturday, November 01, 2008 2:49:36 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.671	BP	1.3424e+005	1.07247e-004	14.39683	Hydrogen
1	0.771	VB	4169.85936	1.05820e-003	4.41256	Oxygen
1	0.873	BB	1.3500e+004	1.24916e-003	16.86357	Nitrogen
1	1.064		-	-	-	CH4
1	1.091	BB	2055.27612	0.00000e+000	0.00000	
1	1.253	BB	1.0943e+004	1.28396e-003	14.05014	CO
2	0.327	BP	165.77019	0.00000e+000	0.00000	
2	0.340	VB	5.4945e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.446	BB	2.6732e+004	7.07067e-005	1.89012	C2H6
2	0.548		-	-	-	C2H2
2	0.686	BB	5.4650e+004	7.69512e-005	4.20539	H2S
2	0.882	BB	2529.13643	6.12584e-005	0.15493	COS
2	1.244	PB	1.1076e+004	6.31895e-005	0.69987	1-2 prop=
2	1.865	PB	2653.43735	5.39101e-005	0.14305	Water
2	2.064		-	-	-	MetyAcetylene
3	0.534	BB	191.55485	1.06494e-004	0.02040	Propylene
3	0.660	BB	1149.76713	1.19217e-004	0.13707	C3
3	0.700	BB	1686.05138	8.80082e-005	0.14839	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.423	BB	572.55123	8.46897e-005	0.04849	i-C5
3	1.550	BB	449.91141	8.37984e-005	0.03770	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	3977.73896	2.88341e-005	0.11469	i-C4

4	0.932	BP	707.29593	0.00000e+000	0.00000	
4	1.007	BP	227.65348	0.00000e+000	0.00000	
4	1.089	BB	354.72941	2.32173e-005	0.00824	n-C6
4	2.843	PP	746.90944	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

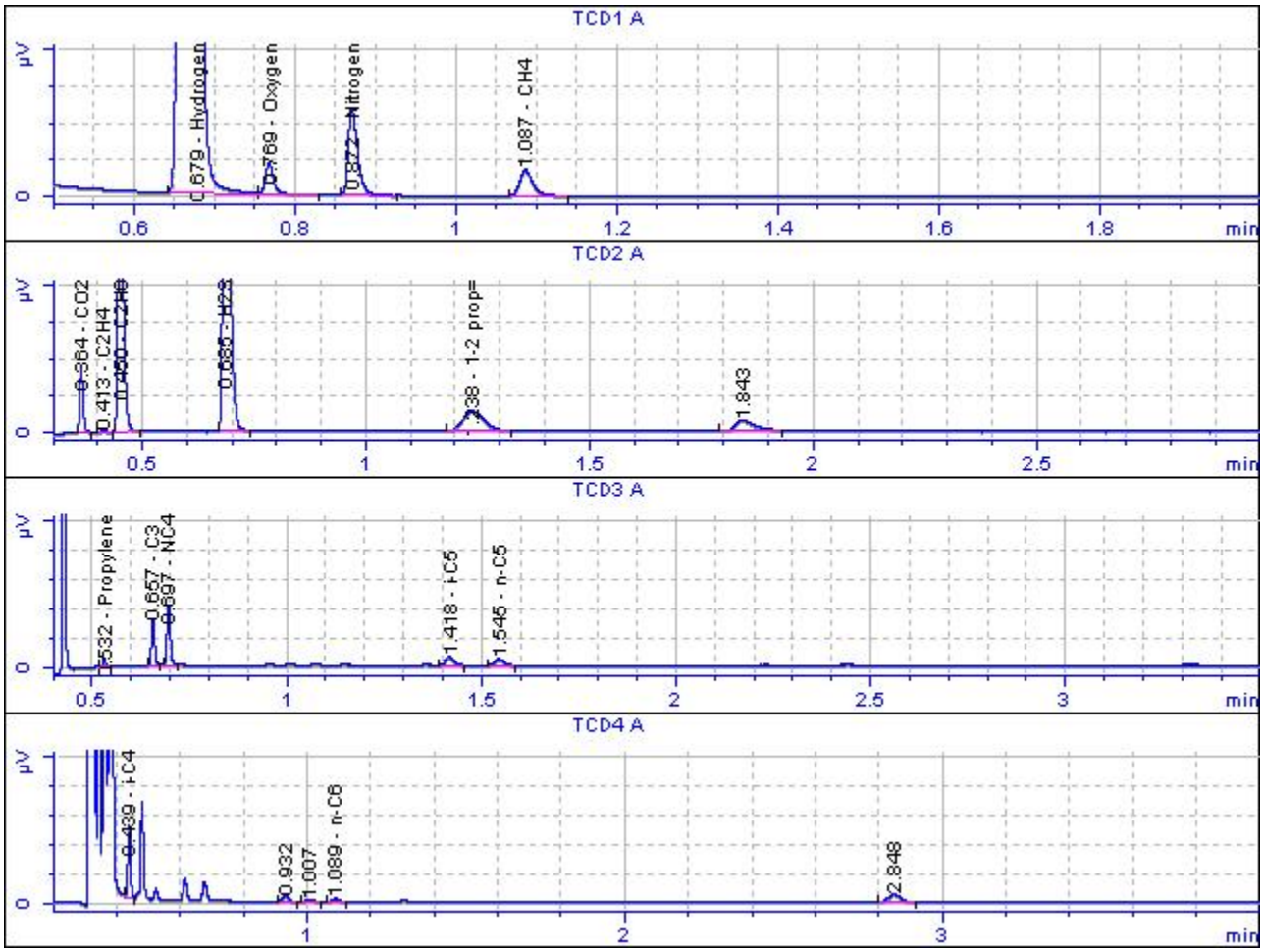
```
Total amount = 57.33143
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO-H(2)-3
Sample note:	Reproducibility run for LGOP with pure H2 , Nov.3, 2008, Final P=353 psi at 24oC
Submission time:	Tuesday, November 04, 2008 9:37:58 AM
Operator:	Aziz
Injection date:	Tuesday, November 04, 2008 9:49:00 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Sunday, November 02, 2008 9:13:49 PM



Norm Percent Report

Calibration last saved:	Sunday, November 02, 2008 9:13:48 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.679	BV	8.0185e+005	1.07247e-004	77.129044	Hydrogen
1	0.769	VB	3148.73872	1.05820e-003	2.988429	Oxygen
1	0.872	BB	9604.40035	1.24916e-003	10.760361	Nitrogen
1	1.087	BB	4005.98282	5.11801e-004	1.838856	CH4
1	1.259		-	-	-	CO
2	0.265	BP	1.8135e+004	0.00000e+000	0.000000	
2	0.364	BB	4703.22297	7.73596e-005	0.326323	CO2
2	0.413	PP	65.94681	7.61229e-004	0.045024	C2H4
2	0.450	BB	3.4377e+004	7.07067e-005	2.180027	C2H6
2	0.548		-	-	-	C2H2
2	0.685	BB	5.6258e+004	7.69512e-005	3.882707	H2S
2	0.872		-	-	-	COS
2	1.238	PB	8766.70602	6.31895e-005	0.496843	1-2 prop=
2	1.843	PB	4393.10635	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.532	BB	135.48883	1.06494e-004	0.012941	Propylene
3	0.657	BB	932.46212	1.19217e-004	0.099703	C3
3	0.697	BB	1315.57511	8.80082e-005	0.103843	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.418	PB	414.06787	8.46897e-005	0.031451	i-C5
3	1.545	BB	333.09872	8.37984e-005	0.025035	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.439	BBA	2883.86884	2.88341e-005	0.074579	i-C4
4	0.932	BP	443.60727	0.00000e+000	0.000000	

4	1.007	BP	140.45882	0.00000e+000	0.000000	
4	1.089	BB	232.13200	2.32173e-005	0.004834	n-C6
4	2.848	BP	1266.98313	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 02, 2008 9:13:48 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.679	BV	8.0185e+005	1.07247e-004	85.99643	Hydrogen
1	0.769	VB	3148.73872	1.05820e-003	3.33200	Oxygen
1	0.872	BB	9604.40035	1.24916e-003	11.99746	Nitrogen
1	1.087	BB	4005.98282	5.11801e-004	2.05027	CH4
1	1.259		-	-	-	CO
2	0.265	BP	1.8135e+004	0.00000e+000	0.00000	
2	0.364	BB	4703.22297	7.73596e-005	0.36384	CO2
2	0.413	PP	65.94681	7.61229e-004	0.05020	C2H4
2	0.450	BB	3.4377e+004	7.07067e-005	2.43066	C2H6
2	0.548		-	-	-	C2H2
2	0.685	BB	5.6258e+004	7.69512e-005	4.32910	H2S
2	0.872		-	-	-	COS
2	1.238	PB	8766.70602	6.31895e-005	0.55396	1-2 prop=
2	1.843	PB	4393.10635	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.532	BB	135.48883	1.06494e-004	0.01443	Propylene
3	0.657	BB	932.46212	1.19217e-004	0.11117	C3
3	0.697	BB	1315.57511	8.80082e-005	0.11578	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.418	PB	414.06787	8.46897e-005	0.03507	i-C5
3	1.545	BB	333.09872	8.37984e-005	0.02791	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.439	BBA	2883.86884	2.88341e-005	0.08315	i-C4
4	0.932	BP	443.60727	0.00000e+000	0.00000	

4	1.007	BP	140.45882	0.00000e+000	0.00000	
4	1.089	BB	232.13200	2.32173e-005	0.00539	n-C6
4	2.848	BP	1266.98313	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

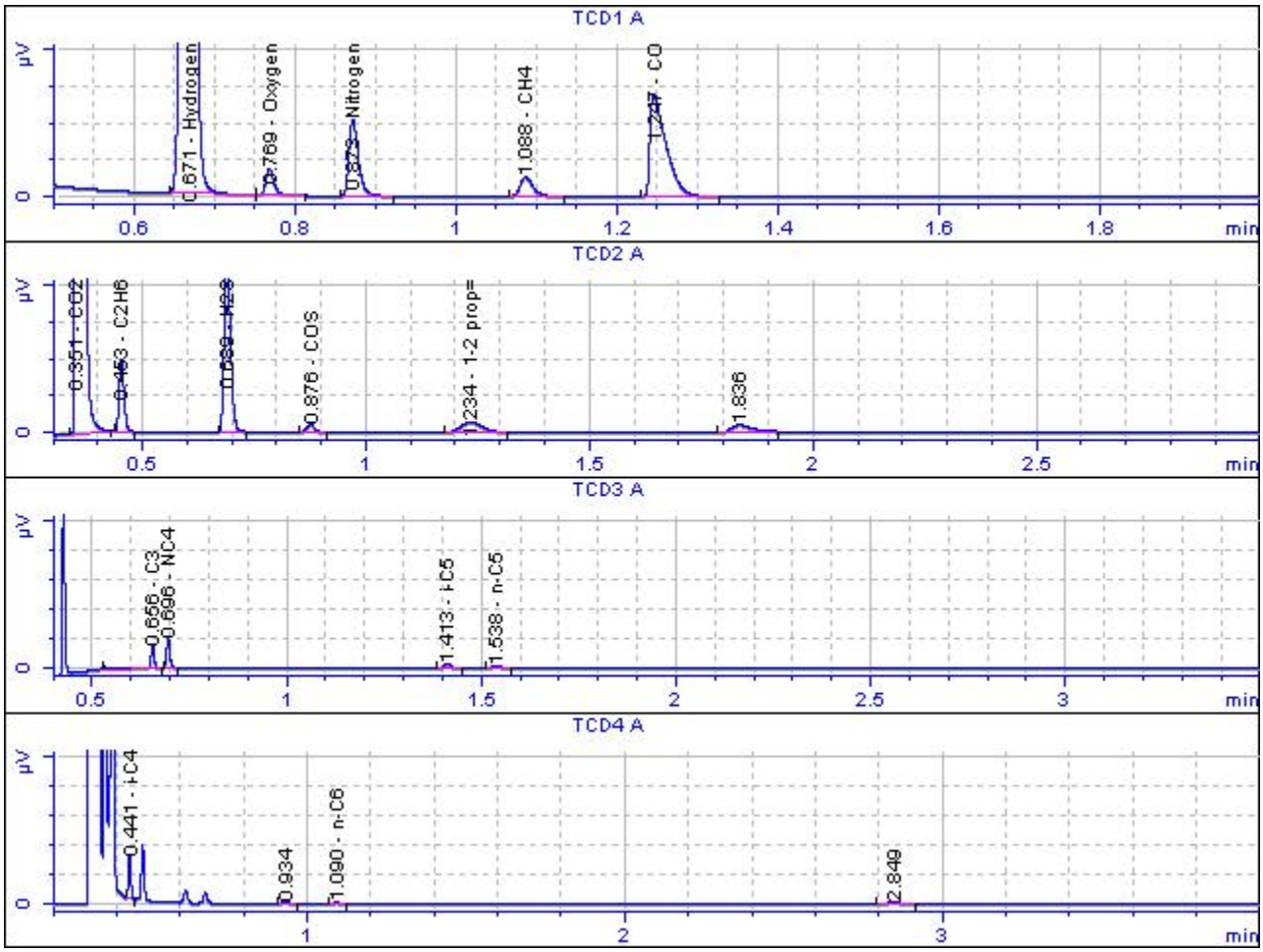
```
Total amount = 111.49682
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGOR2-3
Sample note:	LGO, CO, 10ml Water, 1500ppm pure PMA, 2hrs final P=611psi at 27 oC
Submission time:	Friday, November 07, 2008 9:46:37 AM
Operator:	Aziz
Injection date:	Friday, November 07, 2008 9:57:46 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Sunday, November 02, 2008 9:13:49 PM



Norm Percent Report

Calibration last saved:	Sunday, November 02, 2008 9:13:48 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.671	BP	2.1071e+005	1.07247e-004	22.930098	Hydrogen
1	0.769	VP	2497.04556	1.05820e-003	2.681149	Oxygen
1	0.873	BB	8521.06393	1.24916e-003	10.800368	Nitrogen
1	1.088	BB	2991.20839	5.11801e-004	1.553365	CH4
1	1.247	BB	1.9209e+004	1.28396e-003	25.025552	CO
2	0.267	BP	1.5946e+004	0.00000e+000	0.000000	
2	0.351	BB	4.3263e+005	7.73596e-005	33.959416	CO2
2	0.409		-	-	-	C2H4
2	0.453	BB	7762.25170	7.07067e-005	0.556895	C2H6
2	0.548		-	-	-	C2H2
2	0.689	BB	2.4094e+004	7.69512e-005	1.881264	H2S
2	0.876	BB	1353.31776	6.12584e-005	0.084118	COS
2	1.234	PB	4437.52640	6.31895e-005	0.284519	1-2 prop=
2	1.836	PB	3016.04166	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.523		-	-	-	Propylene
3	0.656	BB	845.81680	1.19217e-004	0.102315	C3
3	0.696	BB	672.22587	8.80082e-005	0.060029	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.413	BB	200.63557	8.46897e-005	0.017241	i-C5
3	1.538	BB	158.51563	8.37984e-005	0.013478	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	1624.82020	2.88341e-005	0.047538	i-C4
4	0.934	BP	231.24383	0.00000e+000	0.000000	

4	1.090	PB	112.64743	2.32173e-005	0.002654	n-C6
4	2.849	PP	426.47876	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 02, 2008 9:13:48 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.671	BP	2.1071e+005	1.07247e-004	22.59853	Hydrogen
1	0.769	VP	2497.04556	1.05820e-003	2.64238	Oxygen
1	0.873	BB	8521.06393	1.24916e-003	10.64420	Nitrogen
1	1.088	BB	2991.20839	5.11801e-004	1.53090	CH4
1	1.247	BB	1.9209e+004	1.28396e-003	24.66369	CO
2	0.267	BP	1.5946e+004	0.00000e+000	0.00000	
2	0.351	BB	4.3263e+005	7.73596e-005	33.46837	CO2
2	0.409		-	-	-	C2H4
2	0.453	BB	7762.25170	7.07067e-005	0.54884	C2H6
2	0.548		-	-	-	C2H2
2	0.689	BB	2.4094e+004	7.69512e-005	1.85406	H2S
2	0.876	BB	1353.31776	6.12584e-005	0.08290	COS
2	1.234	PB	4437.52640	6.31895e-005	0.28041	1-2 prop=
2	1.836	PB	3016.04166	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.523		-	-	-	Propylene
3	0.656	BB	845.81680	1.19217e-004	0.10084	C3
3	0.696	BB	672.22587	8.80082e-005	0.05916	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.413	BB	200.63557	8.46897e-005	0.01699	i-C5
3	1.538	BB	158.51563	8.37984e-005	0.01328	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	1624.82020	2.88341e-005	0.04685	i-C4
4	0.934	BP	231.24383	0.00000e+000	0.00000	

4	1.090	PB	112.64743	2.32173e-005	0.00262	n-C6
4	2.849	PP	426.47876	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

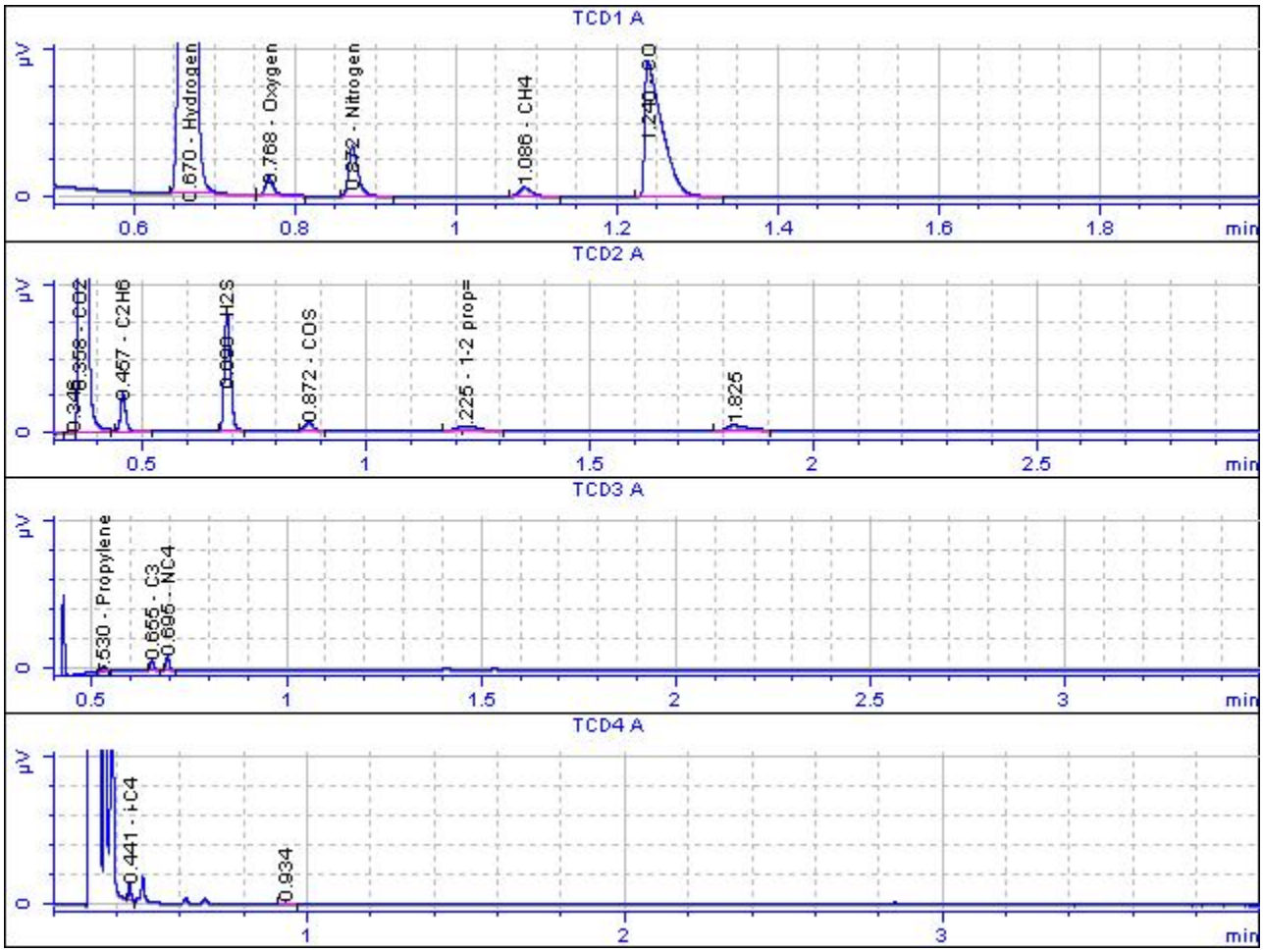
```
Total amount = 98.55402
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO30MIN-3
Sample note:	LGO, over1500ppm pure Mo, CO, 10ml Water at 392oC final P=624psi at 27oC Nov 7, 2008
Submission time:	Saturday, November 08, 2008 1:30:55 PM
Operator:	Aziz
Injection date:	Saturday, November 08, 2008 1:41:47 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Sunday, November 02, 2008 9:13:49 PM



Norm Percent Report

Calibration last saved:	Sunday, November 02, 2008 9:13:48 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.670	BV	2.2306e+005	1.07247e-004	24.594522	Hydrogen
1	0.768	VP	1638.65611	1.05820e-003	1.782725	Oxygen
1	0.872	BB	5466.18511	1.24916e-003	7.019904	Nitrogen
1	1.086	BB	1346.24769	5.11801e-004	0.708360	CH4
1	1.240	BB	2.7663e+004	1.28396e-003	36.515420	CO
2	0.273	BP	3.2287e+004	0.00000e+000	0.000000	
2	0.346	BP	98.41474	0.00000e+000	0.000000	
2	0.358	VB	3.4633e+005	7.73596e-005	27.544326	CO2
2	0.409		-	-	-	C2H4
2	0.457	BB	4233.93892	7.07067e-005	0.307775	C2H6
2	0.548		-	-	-	C2H2
2	0.690	BB	1.5564e+004	7.69512e-005	1.231337	H2S
2	0.872	BB	1380.94490	6.12584e-005	0.086970	COS
2	1.225	BB	1934.64468	6.31895e-005	0.125682	1-2 prop=
2	1.825	PB	2176.92804	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.530	BB	131.34718	1.06494e-004	0.014380	Propylene
3	0.655	BB	189.83083	1.19217e-004	0.023267	C3
3	0.695	BB	291.09969	8.80082e-005	0.026339	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.399		-	-	-	i-C5
3	1.525		-	-	-	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	640.71961	2.88341e-005	0.018993	i-C4

4	0.934	BP	127.81288	0.00000e+000	0.000000	
4	1.092		-	-	-	n-C6
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 02, 2008 9:13:48 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.670	BV	2.2306e+005	1.07247e-004	23.92272	Hydrogen
1	0.768	VP	1638.65611	1.05820e-003	1.73403	Oxygen
1	0.872	BB	5466.18511	1.24916e-003	6.82816	Nitrogen
1	1.086	BB	1346.24769	5.11801e-004	0.68901	CH4
1	1.240	BB	2.7663e+004	1.28396e-003	35.51800	CO
2	0.273	BP	3.2287e+004	0.00000e+000	0.00000	
2	0.346	BP	98.41474	0.00000e+000	0.00000	
2	0.358	VB	3.4633e+005	7.73596e-005	26.79195	CO2
2	0.409		-	-	-	C2H4
2	0.457	BB	4233.93892	7.07067e-005	0.29937	C2H6
2	0.548		-	-	-	C2H2
2	0.690	BB	1.5564e+004	7.69512e-005	1.19770	H2S
2	0.872	BB	1380.94490	6.12584e-005	0.08459	COS
2	1.225	BB	1934.64468	6.31895e-005	0.12225	1-2 prop=
2	1.825	PB	2176.92804	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.530	BB	131.34718	1.06494e-004	0.01399	Propylene
3	0.655	BB	189.83083	1.19217e-004	0.02263	C3
3	0.695	BB	291.09969	8.80082e-005	0.02562	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.399		-	-	-	i-C5
3	1.525		-	-	-	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	640.71961	2.88341e-005	0.01847	i-C4

4	0.934	BP	127.81288	0.00000e+000	0.00000	
4	1.092		-	-	-	n-C6
4	3.726		-	-	-	n-C8

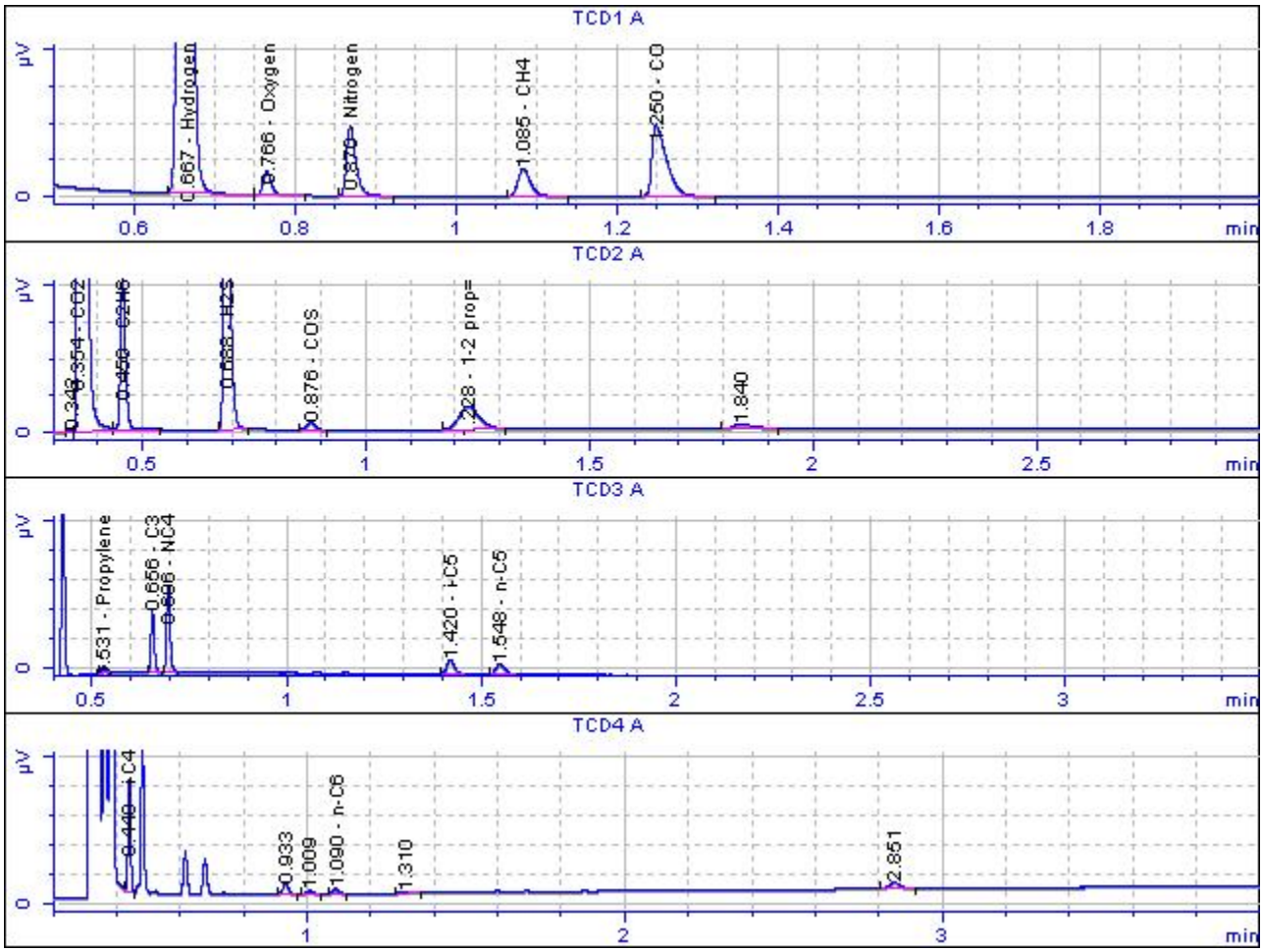
```
Total amount = 97.26850
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO3HRS-3
Sample note:	LGO, pure Mo and CO, 10ml Water @392oC Final P=504, at 25oC Nov.10,2008
Submission time:	Tuesday, November 11, 2008 9:15:32 AM
Operator:	Aziz
Injection date:	Tuesday, November 11, 2008 9:26:57 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Sunday, November 09, 2008 2:59:17 PM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.667	BP	1.9465e+005	1.05208e-004	21.880198	Hydrogen
1	0.766	VP	2327.10716	1.06315e-003	2.643415	Oxygen
1	0.870	BB	7751.11706	1.25339e-003	10.380184	Nitrogen
1	1.085	BB	4186.73970	5.00940e-004	2.240873	CH4
1	1.250	BB	1.2480e+004	1.24655e-003	16.622179	CO
2	0.273	BB	3.5827e+004	0.00000e+000	0.000000	
2	0.342	BP	119.71895	0.00000e+000	0.000000	
2	0.354	VB	5.3017e+005	7.24041e-005	41.014019	CO2
2	0.409		-	-	-	C2H4
2	0.456	BB	1.7248e+004	6.57906e-005	1.212432	C2H6
2	0.548		-	-	-	C2H2
2	0.688	BB	3.8914e+004	7.69512e-005	3.199464	H2S
2	0.876	PB	1170.18012	6.12584e-005	0.076590	COS
2	1.228	BB	9874.87199	1.85836e-005	0.196072	1-2 prop=
2	1.840	PB	2181.85992	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.531	BB	145.68578	9.12409e-005	0.014202	Propylene
3	0.656	BB	1262.81365	1.02067e-004	0.137714	C3
3	0.696	BB	1893.48185	7.65293e-005	0.154826	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.420	BB	662.79816	7.53631e-005	0.053370	i-C5
3	1.548	BB	550.37906	7.49931e-005	0.044100	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.440	BBA	4574.78874	2.45182e-005	0.119844	i-C4

4	0.933	BP	902.30729	0.00000e+000	0.000000	
4	1.009	BP	281.42653	0.00000e+000	0.000000	
4	1.090	BB	482.58029	2.03938e-005	0.010515	n-C6
4	1.310	BP	181.98297	0.00000e+000	0.000000	
4	2.851	PP	948.97434	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.667	BP	1.9465e+005	1.05208e-004	20.47837	Hydrogen
1	0.766	VP	2327.10716	1.06315e-003	2.47406	Oxygen
1	0.870	BB	7751.11706	1.25339e-003	9.71514	Nitrogen
1	1.085	BB	4186.73970	5.00940e-004	2.09730	CH4
1	1.250	BB	1.2480e+004	1.24655e-003	15.55722	CO
2	0.273	BB	3.5827e+004	0.00000e+000	0.00000	
2	0.342	BP	119.71895	0.00000e+000	0.00000	
2	0.354	VB	5.3017e+005	7.24041e-005	38.38632	CO2
2	0.409		-	-	-	C2H4
2	0.456	BB	1.7248e+004	6.57906e-005	1.13475	C2H6
2	0.548		-	-	-	C2H2
2	0.688	BB	3.8914e+004	7.69512e-005	2.99448	H2S
2	0.876	PB	1170.18012	6.12584e-005	0.07168	COS
2	1.228	BB	9874.87199	1.85836e-005	0.18351	1-2 prop=
2	1.840	PB	2181.85992	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.531	BB	145.68578	9.12409e-005	0.01329	Propylene
3	0.656	BB	1262.81365	1.02067e-004	0.12889	C3
3	0.696	BB	1893.48185	7.65293e-005	0.14491	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.420	BB	662.79816	7.53631e-005	0.04995	i-C5
3	1.548	BB	550.37906	7.49931e-005	0.04127	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.440	BBA	4574.78874	2.45182e-005	0.11217	i-C4

4	0.933	BP	902.30729	0.00000e+000	0.00000	
4	1.009	BP	281.42653	0.00000e+000	0.00000	
4	1.090	BB	482.58029	2.03938e-005	0.00984	n-C6
4	1.310	BP	181.98297	0.00000e+000	0.00000	
4	2.851	PP	948.97434	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

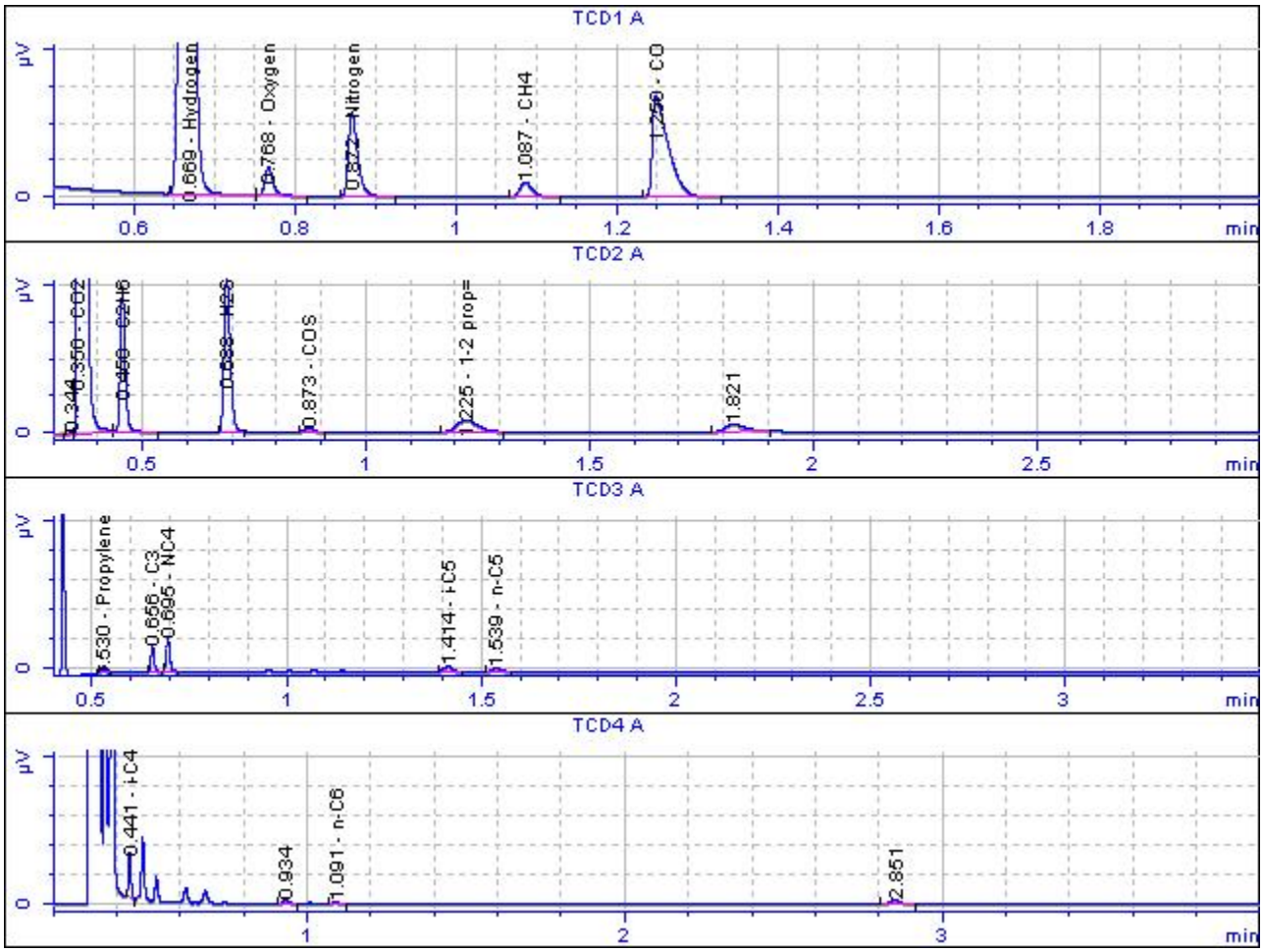
```
Total amount = 93.59317
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGOFe-3
Sample note:	LGO, Mo + Fe and CO, 10ml Water @391oC Final P=666, at 27oC Nov.13,2008
Submission time:	Friday, November 14, 2008 7:58:48 AM
Operator:	Aziz
Injection date:	Friday, November 14, 2008 8:09:42 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Sunday, November 09, 2008 2:59:17 PM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.669	BP	1.9738e+005	1.05208e-004	22.412259	Hydrogen
1	0.768	VP	2759.22829	1.06315e-003	3.165984	Oxygen
1	0.872	BB	9159.45238	1.25339e-003	12.390315	Nitrogen
1	1.087	BB	2221.12452	5.00940e-004	1.200843	CH4
1	1.250	BB	1.8954e+004	1.24655e-003	25.499604	CO
2	0.273	BB	3.3983e+004	0.00000e+000	0.000000	
2	0.344	BP	117.47460	0.00000e+000	0.000000	
2	0.356	VB	4.1111e+005	7.24041e-005	32.125811	CO2
2	0.409		-	-	-	C2H4
2	0.456	BB	1.5668e+004	6.57906e-005	1.112500	C2H6
2	0.548		-	-	-	C2H2
2	0.688	BB	2.0798e+004	7.69512e-005	1.727247	H2S
2	0.873	PP	688.66733	6.12584e-005	0.045531	COS
2	1.225	PB	5132.53606	1.85836e-005	0.102941	1-2 prop=
2	1.821	PB	3181.65588	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.530	BB	144.57348	9.12409e-005	0.014237	Propylene
3	0.656	BB	512.47635	1.02067e-004	0.056453	C3
3	0.695	BB	739.30565	7.65293e-005	0.061063	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.414	BP	238.13899	7.53631e-005	0.019369	i-C5
3	1.539	PB	190.12887	7.49931e-005	0.015389	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	1772.47574	2.45182e-005	0.046903	i-C4

4	0.934	BP	305.67068	0.00000e+000	0.000000	
4	1.091	PB	161.36473	2.03938e-005	0.003552	n-C6
4	2.851	BP	618.82192	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.669	BP	1.9738e+005	1.05208e-004	20.76623	Hydrogen
1	0.768	VP	2759.22829	1.06315e-003	2.93346	Oxygen
1	0.872	BB	9159.45238	1.25339e-003	11.48033	Nitrogen
1	1.087	BB	2221.12452	5.00940e-004	1.11265	CH4
1	1.250	BB	1.8954e+004	1.24655e-003	23.62683	CO
2	0.273	BB	3.3983e+004	0.00000e+000	0.00000	
2	0.344	BP	117.47460	0.00000e+000	0.00000	
2	0.356	VB	4.1111e+005	7.24041e-005	29.76639	CO2
2	0.409		-	-	-	C2H4
2	0.456	BB	1.5668e+004	6.57906e-005	1.03079	C2H6
2	0.548		-	-	-	C2H2
2	0.688	BB	2.0798e+004	7.69512e-005	1.60039	H2S
2	0.873	PP	688.66733	6.12584e-005	0.04219	COS
2	1.225	PB	5132.53606	1.85836e-005	0.09538	1-2 prop=
2	1.821	PB	3181.65588	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.530	BB	144.57348	9.12409e-005	0.01319	Propylene
3	0.656	BB	512.47635	1.02067e-004	0.05231	C3
3	0.695	BB	739.30565	7.65293e-005	0.05658	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.414	BP	238.13899	7.53631e-005	0.01795	i-C5
3	1.539	PB	190.12887	7.49931e-005	0.01426	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BPA	1772.47574	2.45182e-005	0.04346	i-C4

4	0.934	BP	305.67068	0.00000e+000	0.00000	
4	1.091	PB	161.36473	2.03938e-005	0.00329	n-C6
4	2.851	BP	618.82192	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

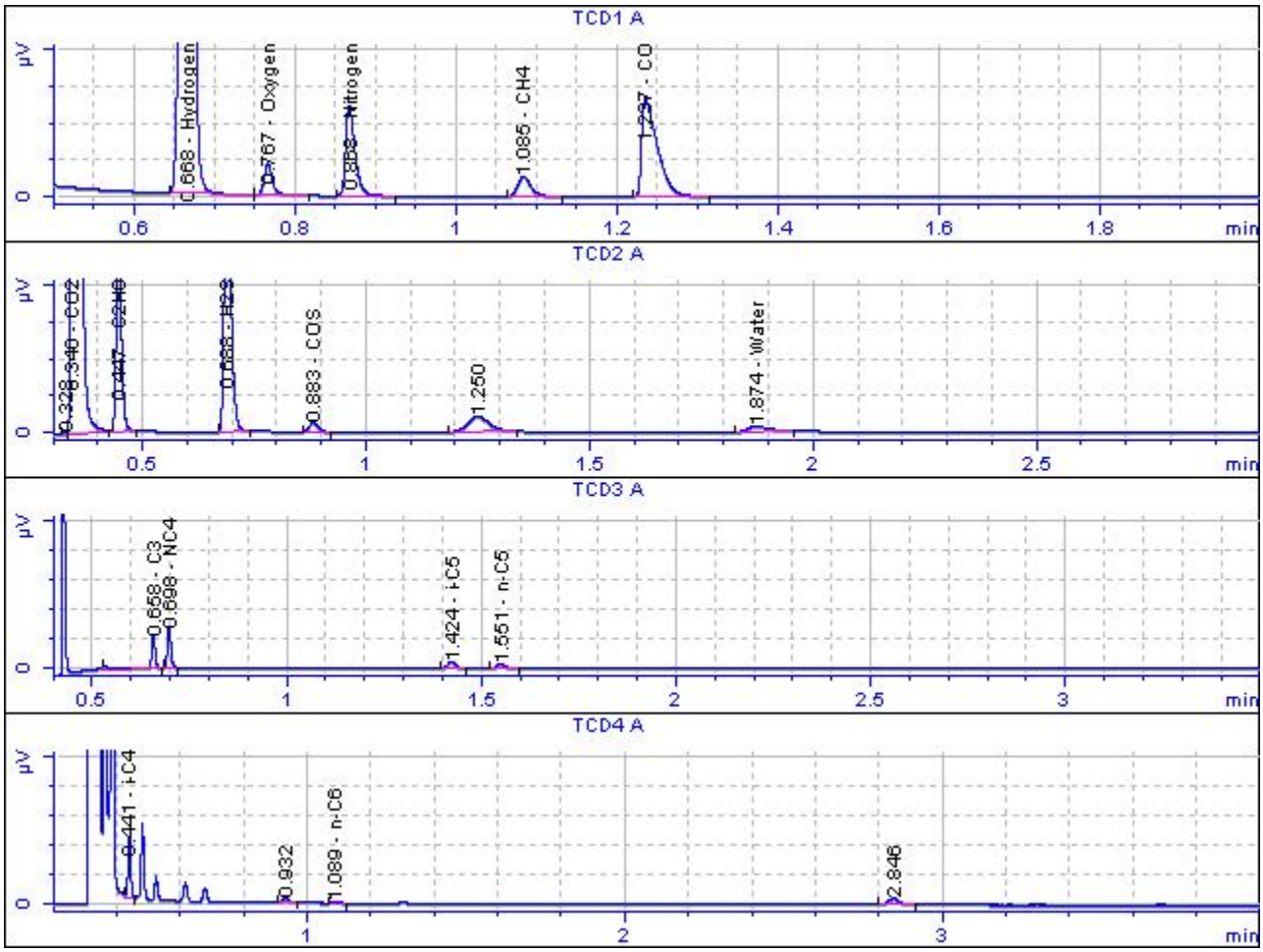
```
Total amount = 92.65568
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGONi-3
Sample note:	LGO, Ni, Oct. 29,2008 , Final P=523 psi @ 24 °C
Submission time:	Thursday, October 30, 2008 7:27:06 AM
Operator:	Aziz
Injection date:	Thursday, October 30, 2008 7:38:17 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Sunday, October 26, 2008 11:37:04 AM



Norm Percent Report

Calibration last saved:	Sunday, October 26, 2008 11:37:04 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.668	BP	1.6065e+005	1.04358e-004	16.952836	Hydrogen
1	0.767	VP	3027.08430	1.05047e-003	3.215456	Oxygen
1	0.868	BB	9980.92391	1.23727e-003	12.487243	Nitrogen
1	1.085	BB	3027.51616	5.07935e-004	1.554989	CH4
1	1.237	BB	1.7978e+004	1.26434e-003	22.984181	CO
2	0.328	BP	148.01048	0.00000e+000	0.000000	
2	0.340	VB	5.0495e+005	7.37434e-005	37.653395	CO2
2	0.409		-	-	-	C2H4
2	0.447	BB	2.1485e+004	6.72729e-005	1.461517	C2H6
2	0.548		-	-	-	C2H2
2	0.688	BB	3.8512e+004	8.11244e-005	3.159218	H2S
2	0.883	BB	1691.12952	6.24614e-005	0.106812	COS
2	1.250	PB	6878.65124	0.00000e+000	0.000000	
2	1.605		-	-	-	1-2 prop=
2	1.874	PB	2221.41048	5.39101e-005	0.121097	Water
2	2.118		-	-	-	MetyAcetylene
3	0.523		-	-	-	Propylene
3	0.658	BB	1001.13009	1.12418e-004	0.113805	C3
3	0.698	BB	903.57933	8.35490e-005	0.076338	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.424	BB	289.58412	8.05434e-005	0.023585	i-C5
3	1.551	BB	219.61722	7.99888e-005	0.017763	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BBA	2438.79977	2.75120e-005	0.067847	i-C4
4	0.932	BP	343.35524	0.00000e+000	0.000000	

4	1.089	PB	169.09485	2.29150e-005	0.003918	n-C6
4	2.846	BP	1010.51715	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, October 26, 2008 11:37:04 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.668	BP	1.6065e+005	1.04358e-004	16.76524	Hydrogen
1	0.767	VP	3027.08430	1.05047e-003	3.17987	Oxygen
1	0.868	BB	9980.92391	1.23727e-003	12.34906	Nitrogen
1	1.085	BB	3027.51616	5.07935e-004	1.53778	CH4
1	1.237	BB	1.7978e+004	1.26434e-003	22.72984	CO
2	0.328	BP	148.01048	0.00000e+000	0.00000	
2	0.340	VB	5.0495e+005	7.37434e-005	37.23672	CO2
2	0.409		-	-	-	C2H4
2	0.447	BB	2.1485e+004	6.72729e-005	1.44534	C2H6
2	0.548		-	-	-	C2H2
2	0.688	BB	3.8512e+004	8.11244e-005	3.12426	H2S
2	0.883	BB	1691.12952	6.24614e-005	0.10563	COS
2	1.250	PB	6878.65124	0.00000e+000	0.00000	
2	1.605		-	-	-	1-2 prop=
2	1.874	PB	2221.41048	5.39101e-005	0.11976	Water
2	2.118		-	-	-	MetyAcetylene
3	0.523		-	-	-	Propylene
3	0.658	BB	1001.13009	1.12418e-004	0.11255	C3
3	0.698	BB	903.57933	8.35490e-005	0.07549	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.424	BB	289.58412	8.05434e-005	0.02332	i-C5
3	1.551	BB	219.61722	7.99888e-005	0.01757	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BBA	2438.79977	2.75120e-005	0.06710	i-C4
4	0.932	BP	343.35524	0.00000e+000	0.00000	

4	1.089	PB	169.09485	2.29150e-005	0.00387	n-C6
4	2.846	BP	1010.51715	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

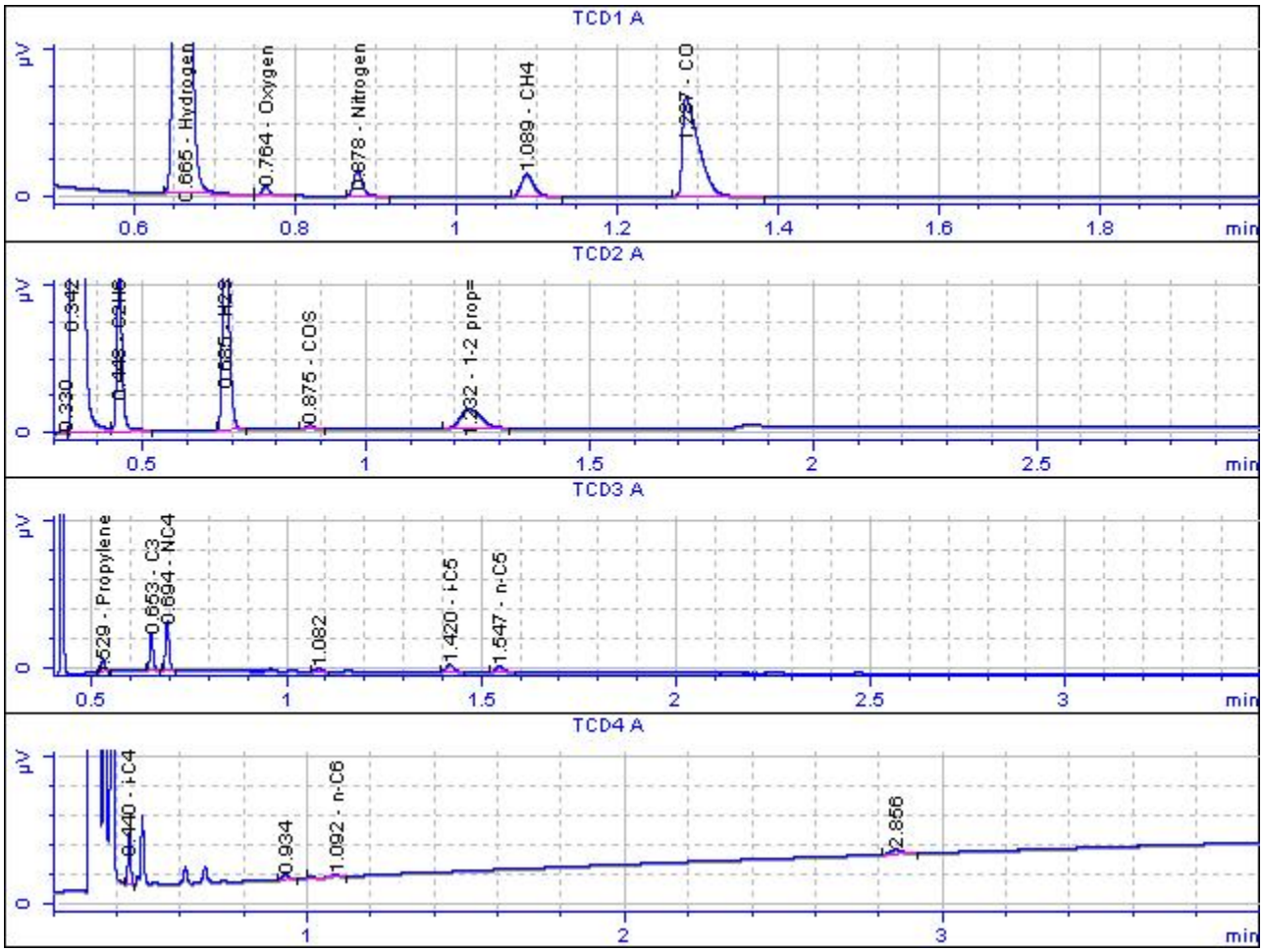
```
Total amount = 98.89340
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGOV2-3
Sample note:	LGO with 0.6 V and final P=559 psi
Submission time:	Friday, January 30, 2009 9:30:36 AM
Operator:	Aziz
Injection date:	Friday, January 30, 2009 9:41:46 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Wednesday, December 17, 2008 10:10:47 AM



Norm Percent Report

Calibration last saved:	Wednesday, December 17, 2008 10:10:46 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.665	BV	2.8219e+005	1.05208e-004	46.838270	Hydrogen
1	0.764	VP	757.44472	1.06315e-003	1.270421	Oxygen
1	0.878	BB	2698.87617	1.25339e-003	5.336684	Nitrogen
1	1.089	BB	3353.64998	5.00940e-004	2.650372	CH4
1	1.287	BB	1.9031e+004	1.24655e-003	37.426160	CO
2	0.330	PP	128.10436	0.00000e+000	0.000000	
2	0.342	VB	6.2319e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	1.7834e+004	6.57906e-005	1.851054	C2H6
2	0.548		-	-	-	C2H2
2	0.685	BB	3.1571e+004	7.69512e-005	3.832680	H2S
2	0.875	BB	778.73745	6.12584e-005	0.075259	COS
2	1.232	PB	8872.86691	1.85836e-005	0.260134	1-2 prop=
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.529	BB	279.82209	9.12409e-005	0.040279	Propylene
3	0.653	BB	761.30520	1.02067e-004	0.122588	C3
3	0.694	BB	1081.81903	7.65293e-005	0.130613	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.082	PP	88.66276	0.00000e+000	0.000000	
3	1.126		-	-	-	c-2-C4=
3	1.420	BB	335.01354	7.53631e-005	0.039831	i-C5
3	1.547	BB	310.97298	7.49931e-005	0.036792	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.440	BPA	2010.25556	2.45182e-005	0.077758	i-C4

4	0.934	BP	389.93395	0.00000e+000	0.000000	
4	1.092	BB	345.17905	2.03938e-005	0.011106	n-C6
4	2.856	PP	726.22147	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Wednesday, December 17, 2008 10:10:46 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.665	BV	2.8219e+005	1.05208e-004	29.68911	Hydrogen
1	0.764	VP	757.44472	1.06315e-003	0.80527	Oxygen
1	0.878	BB	2698.87617	1.25339e-003	3.38273	Nitrogen
1	1.089	BB	3353.64998	5.00940e-004	1.67998	CH4
1	1.287	BB	1.9031e+004	1.24655e-003	23.72311	CO
2	0.330	PP	128.10436	0.00000e+000	0.00000	
2	0.342	VB	6.2319e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	1.7834e+004	6.57906e-005	1.17332	C2H6
2	0.548		-	-	-	C2H2
2	0.685	BB	3.1571e+004	7.69512e-005	2.42940	H2S
2	0.875	BB	778.73745	6.12584e-005	0.04770	COS
2	1.232	PB	8872.86691	1.85836e-005	0.16489	1-2 prop=
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.529	BB	279.82209	9.12409e-005	0.02553	Propylene
3	0.653	BB	761.30520	1.02067e-004	0.07770	C3
3	0.694	BB	1081.81903	7.65293e-005	0.08279	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.082	PP	88.66276	0.00000e+000	0.00000	
3	1.126		-	-	-	c-2-C4=
3	1.420	BB	335.01354	7.53631e-005	0.02525	i-C5
3	1.547	BB	310.97298	7.49931e-005	0.02332	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.440	BPA	2010.25556	2.45182e-005	0.04929	i-C4

4	0.934	BP	389.93395	0.00000e+000	0.00000	
4	1.092	BB	345.17905	2.03938e-005	0.00704	n-C6
4	2.856	PP	726.22147	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

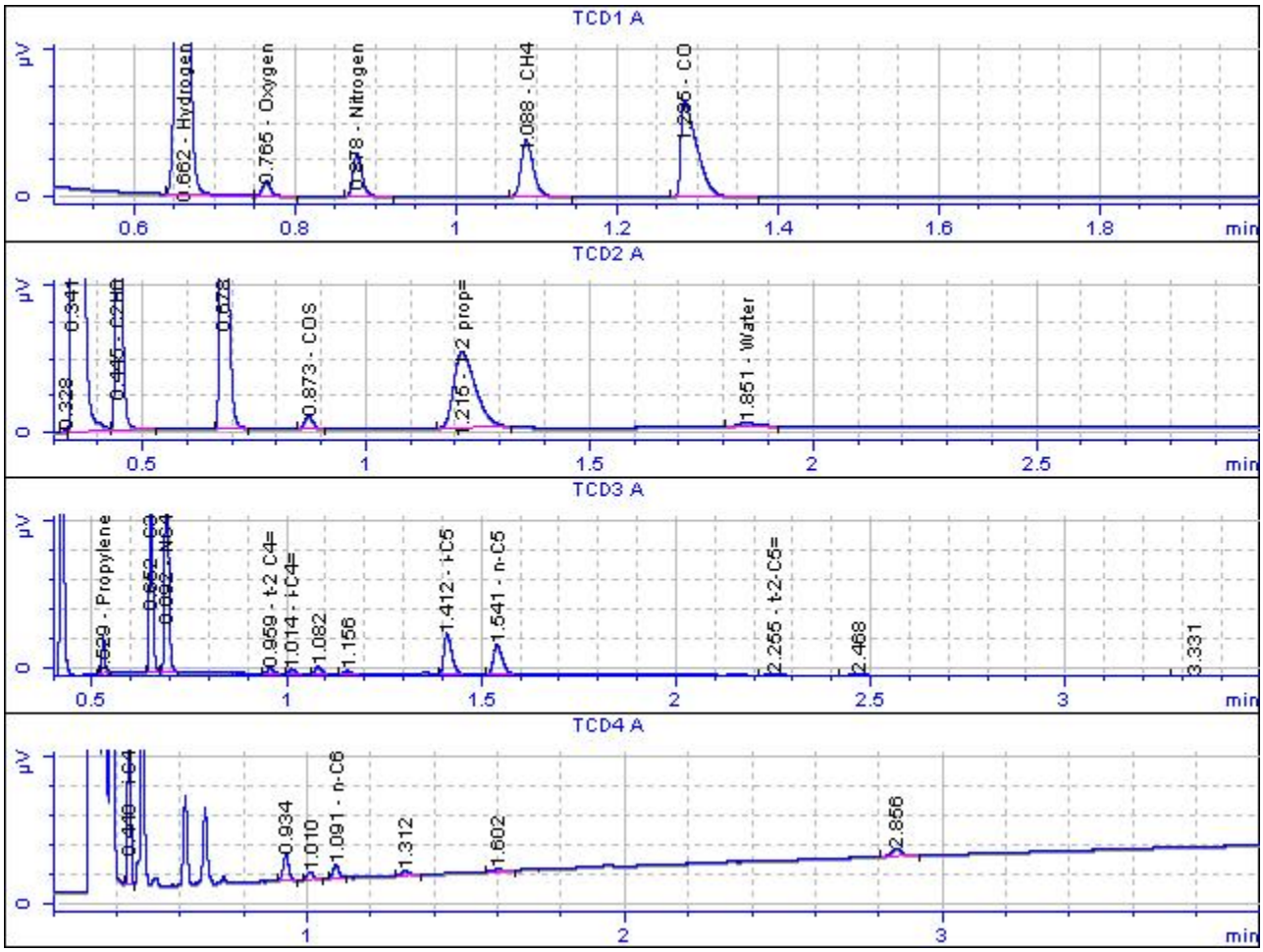
```
Total amount = 63.38644
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO410T-3
Sample note:	LGO at T=410 C and final P=543 psi
Submission time:	Wednesday, January 28, 2009 10:20:37 AM
Operator:	Aziz
Injection date:	Wednesday, January 28, 2009 10:31:47 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Wednesday, December 17, 2008 10:10:47 AM



Norm Percent Report

Calibration last saved:	Wednesday, December 17, 2008 10:10:46 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.662	BP	1.1656e+005	1.05208e-004	23.428213	Hydrogen
1	0.765	VP	1355.85862	1.06315e-003	2.753823	Oxygen
1	0.878	BB	4611.64249	1.25339e-003	11.042542	Nitrogen
1	1.088	BB	8368.69920	5.00940e-004	8.008884	CH4
1	1.285	BB	1.8220e+004	1.24655e-003	43.390461	CO
2	0.328	PP	134.30957	0.00000e+000	0.000000	
2	0.341	VV	7.3918e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.445	VB	5.4889e+004	6.57906e-005	6.898810	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	6.9662e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.873	BB	2158.27090	6.12584e-005	0.252581	COS
2	1.215	PB	3.5497e+004	1.85836e-005	1.260227	1-2 prop=
2	1.851	PB	1713.06114	5.39101e-005	0.176430	Water
2	2.064		-	-	-	MetyAcetylene
3	0.529	BB	721.93372	9.12409e-005	0.125839	Propylene
3	0.652	BV	3909.61339	1.02067e-004	0.762336	C3
3	0.692	VB	5550.70719	7.65293e-005	0.811530	NC4
3	0.959	PB	181.02698	8.11249e-005	0.028056	t-2 C4=
3	1.014	BB	133.02120	8.13163e-005	0.020665	i-C4=
3	1.052		-	-	-	1-C4=
3	1.082	BB	251.99476	0.00000e+000	0.000000	
3	1.126		-	-	-	c-2-C4=
3	1.156	PP	106.83955	0.00000e+000	0.000000	
3	1.412	BB	1861.59070	7.53631e-005	0.268023	i-C5
3	1.541	BB	1571.92497	7.49931e-005	0.225207	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.255	PB	80.59258	7.55332e-005	0.011630	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.468	BB	136.98986	0.00000e+000	0.000000	

3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.331	PB	159.55199	0.00000e+000	0.000000	
3	3.801	BB	735.41964	0.00000e+000	0.000000	
4	0.440	BBA	1.0392e+004	2.45182e-005	0.486758	i-C4
4	0.934	BB	2194.58616	0.00000e+000	0.000000	
4	1.010	BP	749.19516	0.00000e+000	0.000000	
4	1.091	BB	1231.67224	2.03938e-005	0.047987	n-C6
4	1.312	BP	471.36338	0.00000e+000	0.000000	
4	1.602	PB	353.80645	0.00000e+000	0.000000	
4	2.856	PP	1189.87421	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Wednesday, December 17, 2008 10:10:46 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.662	BP	1.1656e+005	1.05208e-004	12.26339	Hydrogen
1	0.765	VP	1355.85862	1.06315e-003	1.44148	Oxygen
1	0.878	BB	4611.64249	1.25339e-003	5.78017	Nitrogen
1	1.088	BB	8368.69920	5.00940e-004	4.19221	CH4
1	1.285	BB	1.8220e+004	1.24655e-003	22.71254	CO
2	0.328	PP	134.30957	0.00000e+000	0.00000	
2	0.341	VV	7.3918e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.445	VB	5.4889e+004	6.57906e-005	3.61115	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	6.9662e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.873	BB	2158.27090	6.12584e-005	0.13221	COS
2	1.215	PB	3.5497e+004	1.85836e-005	0.65966	1-2 prop=
2	1.851	PB	1713.06114	5.39101e-005	0.09235	Water
2	2.064		-	-	-	MetyAcetylene
3	0.529	BB	721.93372	9.12409e-005	0.06587	Propylene
3	0.652	BV	3909.61339	1.02067e-004	0.39904	C3
3	0.692	VB	5550.70719	7.65293e-005	0.42479	NC4
3	0.959	PB	181.02698	8.11249e-005	0.01469	t-2 C4=
3	1.014	BB	133.02120	8.13163e-005	0.01082	i-C4=
3	1.052		-	-	-	1-C4=
3	1.082	BB	251.99476	0.00000e+000	0.00000	
3	1.126		-	-	-	c-2-C4=
3	1.156	PP	106.83955	0.00000e+000	0.00000	
3	1.412	BB	1861.59070	7.53631e-005	0.14030	i-C5
3	1.541	BB	1571.92497	7.49931e-005	0.11788	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.255	PB	80.59258	7.55332e-005	0.00609	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.468	BB	136.98986	0.00000e+000	0.00000	

3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.331	PB	159.55199	0.00000e+000	0.00000	
3	3.801	BB	735.41964	0.00000e+000	0.00000	
4	0.440	BBA	1.0392e+004	2.45182e-005	0.25479	i-C4
4	0.934	BB	2194.58616	0.00000e+000	0.00000	
4	1.010	BP	749.19516	0.00000e+000	0.00000	
4	1.091	BB	1231.67224	2.03938e-005	0.02512	n-C6
4	1.312	BP	471.36338	0.00000e+000	0.00000	
4	1.602	PB	353.80645	0.00000e+000	0.00000	
4	2.856	PP	1189.87421	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

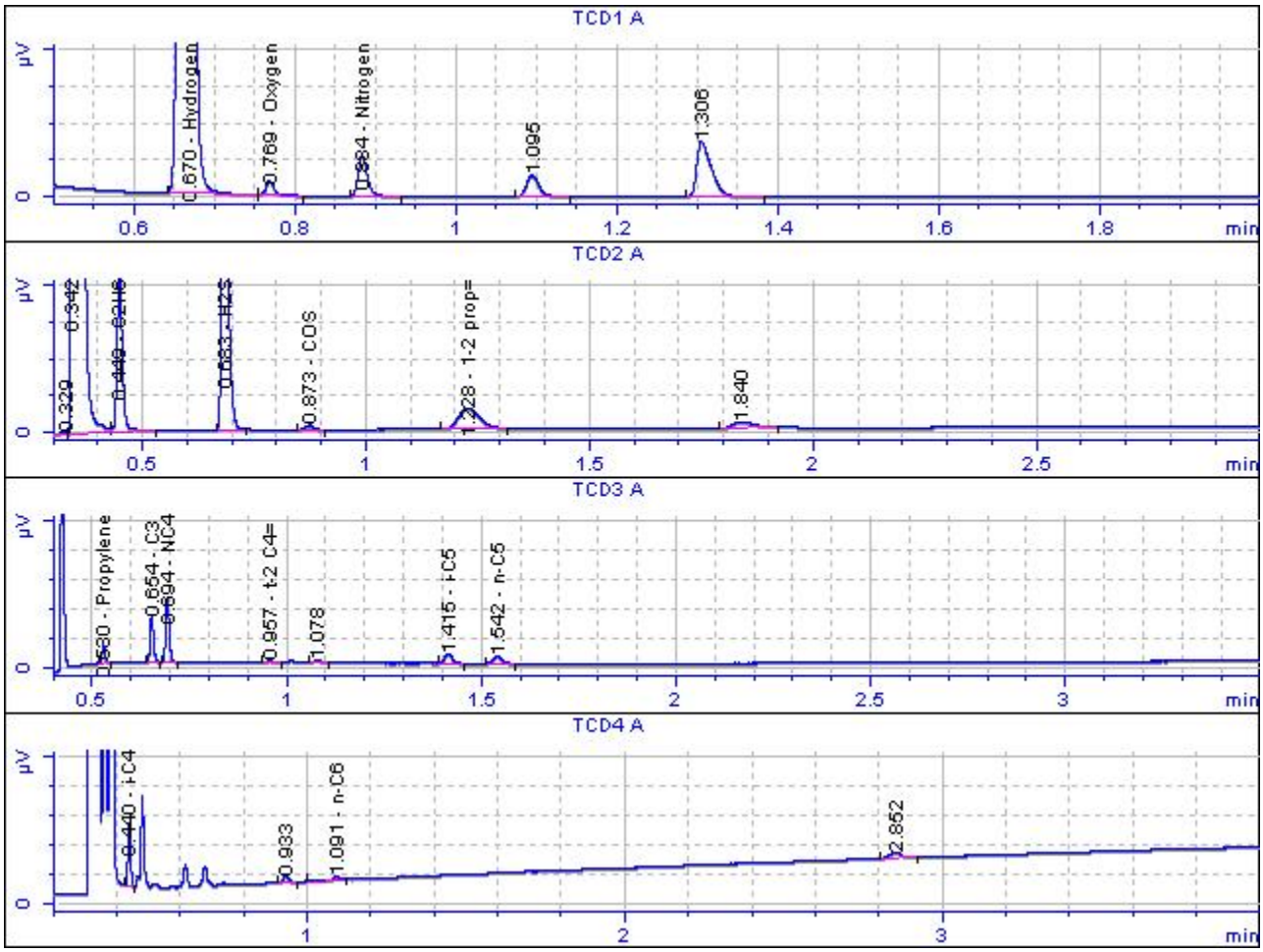
```
Total amount = 52.34455
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO15W-3
Sample note:	LGO with 15ML WATER UNDER CO and final P=457 psi
Submission time:	Tuesday, February 03, 2009 9:19:47 AM
Operator:	Aziz
Injection date:	Tuesday, February 03, 2009 9:30:56 AM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Chris_Sulfur
Method last saved:	Wednesday, December 17, 2008 10:10:47 AM



Norm Percent Report

Calibration last saved:	Wednesday, December 17, 2008 10:10:46 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.670	BV	3.0296e+005	1.05208e-004	73.129979	Hydrogen
1	0.769	VP	1298.34664	1.06315e-003	3.167000	Oxygen
1	0.884	BB	4400.70976	1.25339e-003	12.655281	Nitrogen
1	1.064		-	-	-	CH4
1	1.095	BB	3141.38509	0.00000e+000	0.000000	
1	1.259		-	-	-	CO
1	1.306	BB	9592.06932	0.00000e+000	0.000000	
2	0.329	PV	316.23692	0.00000e+000	0.000000	
2	0.342	VV	7.2846e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.449	VB	1.7720e+004	6.57906e-005	2.674851	C2H6
2	0.548		-	-	-	C2H2
2	0.683	BB	3.9575e+004	7.69512e-005	6.987132	H2S
2	0.873	PB	753.20818	6.12584e-005	0.105863	COS
2	1.228	PB	9321.79328	1.85836e-005	0.397460	1-2 prop=
2	1.840	PB	2659.85316	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.530	BB	343.78325	9.12409e-005	0.071968	Propylene
3	0.654	PB	968.68707	1.02067e-004	0.226846	C3
3	0.694	BB	1424.22171	7.65293e-005	0.250075	NC4
3	0.957	PP	86.84649	8.11249e-005	0.016165	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.078	PP	110.72711	0.00000e+000	0.000000	
3	1.126		-	-	-	c-2-C4=
3	1.415	BB	451.35062	7.53631e-005	0.078044	i-C5
3	1.542	BB	403.79513	7.49931e-005	0.069478	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=

3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.440	BBA	2656.46999	2.45182e-005	0.149437	i-C4
4	0.933	BP	530.49073	0.00000e+000	0.000000	
4	1.091	BB	436.45710	2.03938e-005	0.020422	n-C6
4	2.852	PP	1015.81707	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Wednesday, December 17, 2008 10:10:46 AM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.670	BV	3.0296e+005	1.05208e-004	31.87361	Hydrogen
1	0.769	VP	1298.34664	1.06315e-003	1.38033	Oxygen
1	0.884	BB	4400.70976	1.25339e-003	5.51579	Nitrogen
1	1.064		-	-	-	CH4
1	1.095	BB	3141.38509	0.00000e+000	0.00000	
1	1.259		-	-	-	CO
1	1.306	BB	9592.06932	0.00000e+000	0.00000	
2	0.329	PV	316.23692	0.00000e+000	0.00000	
2	0.342	VV	7.2846e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.449	VB	1.7720e+004	6.57906e-005	1.16583	C2H6
2	0.548		-	-	-	C2H2
2	0.683	BB	3.9575e+004	7.69512e-005	3.04533	H2S
2	0.873	PB	753.20818	6.12584e-005	0.04614	COS
2	1.228	PB	9321.79328	1.85836e-005	0.17323	1-2 prop=
2	1.840	PB	2659.85316	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.530	BB	343.78325	9.12409e-005	0.03137	Propylene
3	0.654	PB	968.68707	1.02067e-004	0.09887	C3
3	0.694	BB	1424.22171	7.65293e-005	0.10899	NC4
3	0.957	PP	86.84649	8.11249e-005	0.00705	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.078	PP	110.72711	0.00000e+000	0.00000	
3	1.126		-	-	-	c-2-C4=
3	1.415	BB	451.35062	7.53631e-005	0.03402	i-C5
3	1.542	BB	403.79513	7.49931e-005	0.03028	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=

3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.440	BBA	2656.46999	2.45182e-005	0.06513	i-C4
4	0.933	BP	530.49073	0.00000e+000	0.00000	
4	1.091	BB	436.45710	2.03938e-005	0.00890	n-C6
4	2.852	PP	1015.81707	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

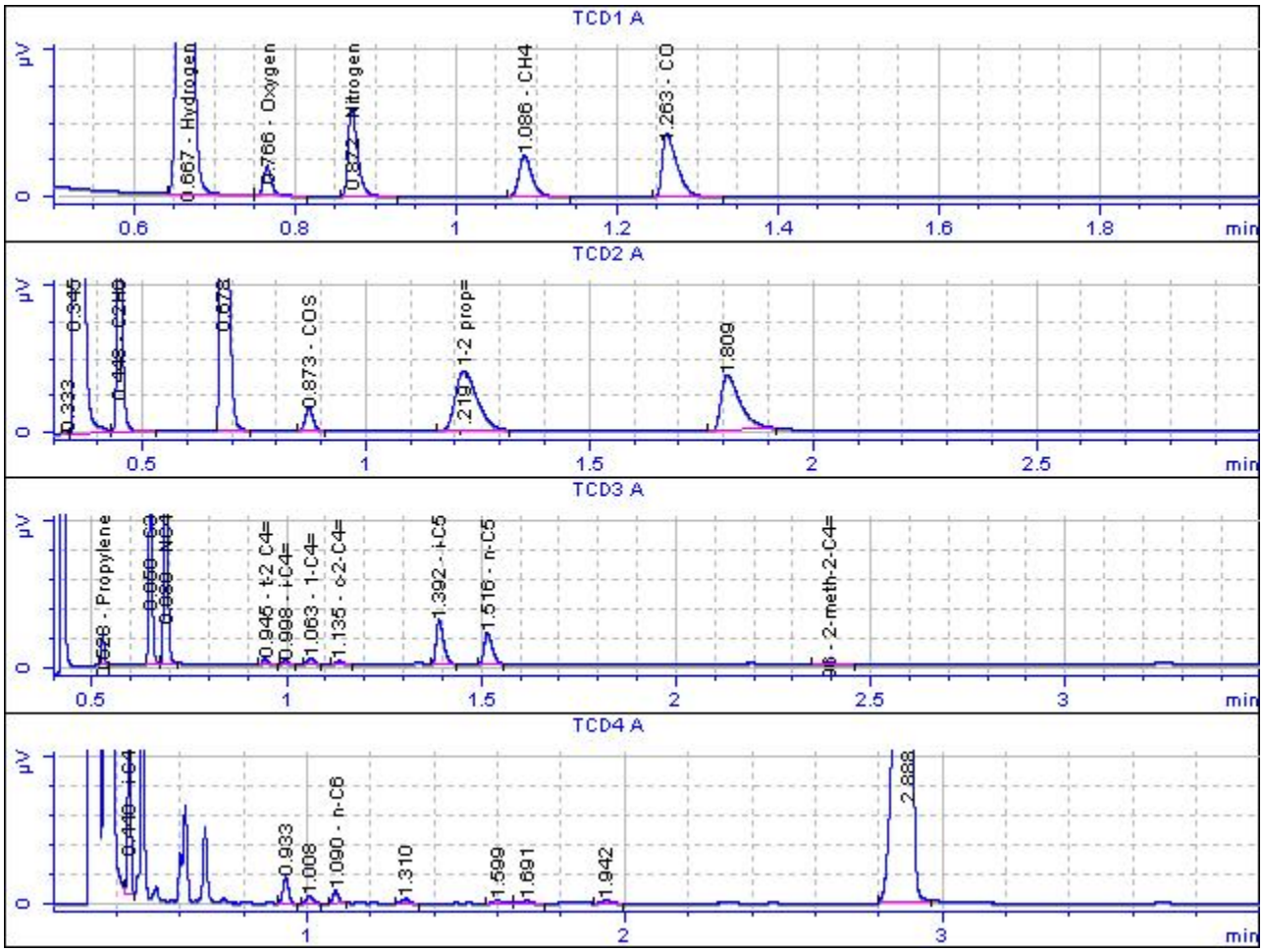
```
Total amount = 43.58488
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO60CO, 120min
Sample note:	60 CO in lagre reactor at time =120
Submission time:	Tuesday, May 19, 2009 2:33:45 PM
Operator:	Aziz
Injection date:	Tuesday, May 19, 2009 2:34:31 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.667	BP	2.0069e+005	1.05208e-004	36.612738	Hydrogen
1	0.766	VP	2825.50877	1.06315e-003	5.208828	Oxygen
1	0.872	BB	9989.76661	1.25339e-003	21.711530	Nitrogen
1	1.086	BB	6353.70121	5.00940e-004	5.519027	CH4
1	1.263	BB	1.1153e+004	1.24655e-003	24.108374	CO
2	0.333	PP	108.34654	0.00000e+000	0.000000	
2	0.345	VB	5.2128e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	2.6991e+004	6.57906e-005	3.079144	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	7.6787e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.873	BB	3904.47113	6.12584e-005	0.414742	COS
2	1.219	PB	2.8195e+004	1.85836e-005	0.908561	1-2 prop=
2	1.809	PB	2.2869e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.528	BB	556.37788	9.12409e-005	0.088026	Propylene
3	0.650	BV	3581.77073	1.02067e-004	0.633917	C3
3	0.689	VB	5292.96142	7.65293e-005	0.702387	NC4
3	0.945	BB	145.38380	8.11249e-005	0.020451	t-2 C4=
3	0.998	BB	116.86265	8.13163e-005	0.016478	i-C4=
3	1.063	BP	208.85915	8.30556e-005	0.030080	1-C4=
3	1.135	BP	91.96657	8.29864e-005	0.013234	c-2-C4=
3	1.392	BB	1951.72805	7.53631e-005	0.255052	i-C5
3	1.516	BB	1547.70501	7.49931e-005	0.201261	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.396	PP	94.81328	7.78266e-005	0.012795	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.699	BB	841.27694	0.00000e+000	0.000000	
4	0.440	BBA	9960.78918	2.45182e-005	0.423480	i-C4
4	0.933	BP	2175.45857	0.00000e+000	0.000000	
4	1.008	BP	701.72232	0.00000e+000	0.000000	
4	1.090	BB	1128.18221	2.03938e-005	0.039896	n-C6
4	1.310	BP	467.21941	0.00000e+000	0.000000	
4	1.599	PB	443.89858	0.00000e+000	0.000000	
4	1.691	BP	363.04522	0.00000e+000	0.000000	
4	1.942	PB	359.91700	0.00000e+000	0.000000	
4	2.888	BB	1.4365e+005	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.667	BP	2.0069e+005	1.05208e-004	21.11456	Hydrogen
1	0.766	VP	2825.50877	1.06315e-003	3.00393	Oxygen
1	0.872	BB	9989.76661	1.25339e-003	12.52104	Nitrogen
1	1.086	BB	6353.70121	5.00940e-004	3.18282	CH4
1	1.263	BB	1.1153e+004	1.24655e-003	13.90329	CO
2	0.333	PP	108.34654	0.00000e+000	0.00000	
2	0.345	VB	5.2128e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	2.6991e+004	6.57906e-005	1.77574	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	7.6787e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.873	BB	3904.47113	6.12584e-005	0.23918	COS
2	1.219	PB	2.8195e+004	1.85836e-005	0.52397	1-2 prop=
2	1.809	PB	2.2869e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.528	BB	556.37788	9.12409e-005	0.05076	Propylene
3	0.650	BV	3581.77073	1.02067e-004	0.36558	C3
3	0.689	VB	5292.96142	7.65293e-005	0.40507	NC4
3	0.945	BB	145.38380	8.11249e-005	0.01179	t-2 C4=
3	0.998	BB	116.86265	8.13163e-005	0.00950	i-C4=
3	1.063	BP	208.85915	8.30556e-005	0.01735	1-C4=
3	1.135	BP	91.96657	8.29864e-005	0.00763	c-2-C4=
3	1.392	BB	1951.72805	7.53631e-005	0.14709	i-C5
3	1.516	BB	1547.70501	7.49931e-005	0.11607	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.396	PP	94.81328	7.78266e-005	0.00738	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.699	BB	841.27694	0.00000e+000	0.00000	
4	0.440	BBA	9960.78918	2.45182e-005	0.24422	i-C4
4	0.933	BP	2175.45857	0.00000e+000	0.00000	
4	1.008	BP	701.72232	0.00000e+000	0.00000	
4	1.090	BB	1128.18221	2.03938e-005	0.02301	n-C6
4	1.310	BP	467.21941	0.00000e+000	0.00000	
4	1.599	PB	443.89858	0.00000e+000	0.00000	
4	1.691	BP	363.04522	0.00000e+000	0.00000	
4	1.942	PB	359.91700	0.00000e+000	0.00000	
4	2.888	BB	1.4365e+005	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

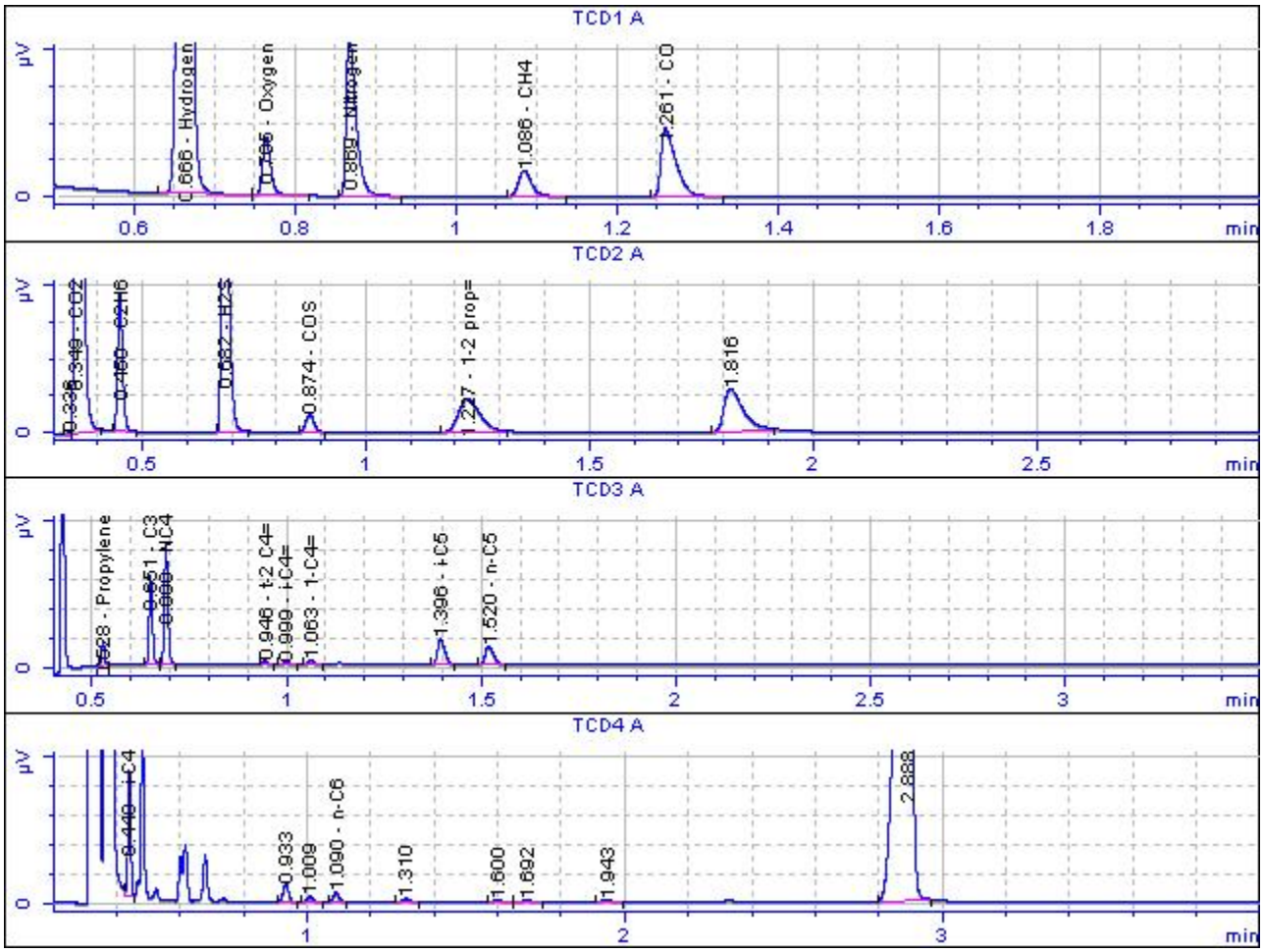
Total amount = 57.66998

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO60CO, 90min
Sample note:	60 CO in lagre reactor at time =90
Submission time:	Tuesday, May 19, 2009 2:03:43 PM
Operator:	Aziz
Injection date:	Tuesday, May 19, 2009 2:04:30 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.666	BP	1.8920e+005	1.05208e-004	19.855820	Hydrogen
1	0.765	VP	5471.65545	1.06315e-003	5.802533	Oxygen
1	0.869	BB	1.8904e+004	1.25339e-003	23.634177	Nitrogen
1	1.086	BB	4024.82623	5.00940e-004	2.011122	CH4
1	1.261	BB	1.1984e+004	1.24655e-003	14.900416	CO
2	0.336	PP	74.88780	0.00000e+000	0.000000	
2	0.349	VB	3.8259e+005	7.24041e-005	27.631600	CO2
2	0.409		-	-	-	C2H4
2	0.450	PB	1.4543e+004	6.57906e-005	0.954357	C2H6
2	0.548		-	-	-	C2H2
2	0.682	BB	5.1966e+004	7.69512e-005	3.988800	H2S
2	0.874	BB	3107.73664	6.12584e-005	0.189896	COS
2	1.227	PB	1.4988e+004	1.85836e-005	0.277829	1-2 prop=
2	1.816	PB	1.7220e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.528	BB	472.00479	9.12409e-005	0.042958	Propylene
3	0.651	PV	1761.93088	1.02067e-004	0.179382	C3
3	0.690	VB	2646.09273	7.65293e-005	0.201994	NC4
3	0.946	PB	102.53346	8.11249e-005	0.008297	t-2 C4=
3	0.999	BB	87.98943	8.13163e-005	0.007137	i-C4=
3	1.063	PP	160.43590	8.30556e-005	0.013292	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.396	BB	1113.86258	7.53631e-005	0.083733	i-C5
3	1.520	BB	932.56978	7.49931e-005	0.069760	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.707	BB	526.70569	0.00000e+000	0.000000	
4	0.440	BBA	5313.02246	2.45182e-005	0.129938	i-C4

4	0.933	BP	1551.18010	0.00000e+000	0.000000	
4	1.009	BP	509.74006	0.00000e+000	0.000000	
4	1.090	BB	833.77318	2.03938e-005	0.016961	n-C6
4	1.310	BP	355.21105	0.00000e+000	0.000000	
4	1.600	PB	346.93466	0.00000e+000	0.000000	
4	1.692	BB	283.43570	0.00000e+000	0.000000	
4	1.943	PB	294.05107	0.00000e+000	0.000000	
4	2.888	PB	1.3747e+005	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.666	BP	1.8920e+005	1.05208e-004	19.90591	Hydrogen
1	0.765	VP	5471.65545	1.06315e-003	5.81717	Oxygen
1	0.869	BB	1.8904e+004	1.25339e-003	23.69380	Nitrogen
1	1.086	BB	4024.82623	5.00940e-004	2.01620	CH4
1	1.261	BB	1.1984e+004	1.24655e-003	14.93801	CO
2	0.336	PP	74.88780	0.00000e+000	0.00000	
2	0.349	VB	3.8259e+005	7.24041e-005	27.70131	CO2
2	0.409		-	-	-	C2H4
2	0.450	PB	1.4543e+004	6.57906e-005	0.95676	C2H6
2	0.548		-	-	-	C2H2
2	0.682	BB	5.1966e+004	7.69512e-005	3.99886	H2S
2	0.874	BB	3107.73664	6.12584e-005	0.19037	COS
2	1.227	PB	1.4988e+004	1.85836e-005	0.27853	1-2 prop=
2	1.816	PB	1.7220e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.528	BB	472.00479	9.12409e-005	0.04307	Propylene
3	0.651	PV	1761.93088	1.02067e-004	0.17983	C3
3	0.690	VB	2646.09273	7.65293e-005	0.20250	NC4
3	0.946	PB	102.53346	8.11249e-005	0.00832	t-2 C4=
3	0.999	BB	87.98943	8.13163e-005	0.00715	i-C4=
3	1.063	PP	160.43590	8.30556e-005	0.01333	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.396	BB	1113.86258	7.53631e-005	0.08394	i-C5
3	1.520	BB	932.56978	7.49931e-005	0.06994	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.707	BB	526.70569	0.00000e+000	0.00000	
4	0.440	BBA	5313.02246	2.45182e-005	0.13027	i-C4

4	0.933	BP	1551.18010	0.00000e+000	0.00000	
4	1.009	BP	509.74006	0.00000e+000	0.00000	
4	1.090	BB	833.77318	2.03938e-005	0.01700	n-C6
4	1.310	BP	355.21105	0.00000e+000	0.00000	
4	1.600	PB	346.93466	0.00000e+000	0.00000	
4	1.692	BB	283.43570	0.00000e+000	0.00000	
4	1.943	PB	294.05107	0.00000e+000	0.00000	
4	2.888	PB	1.3747e+005	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

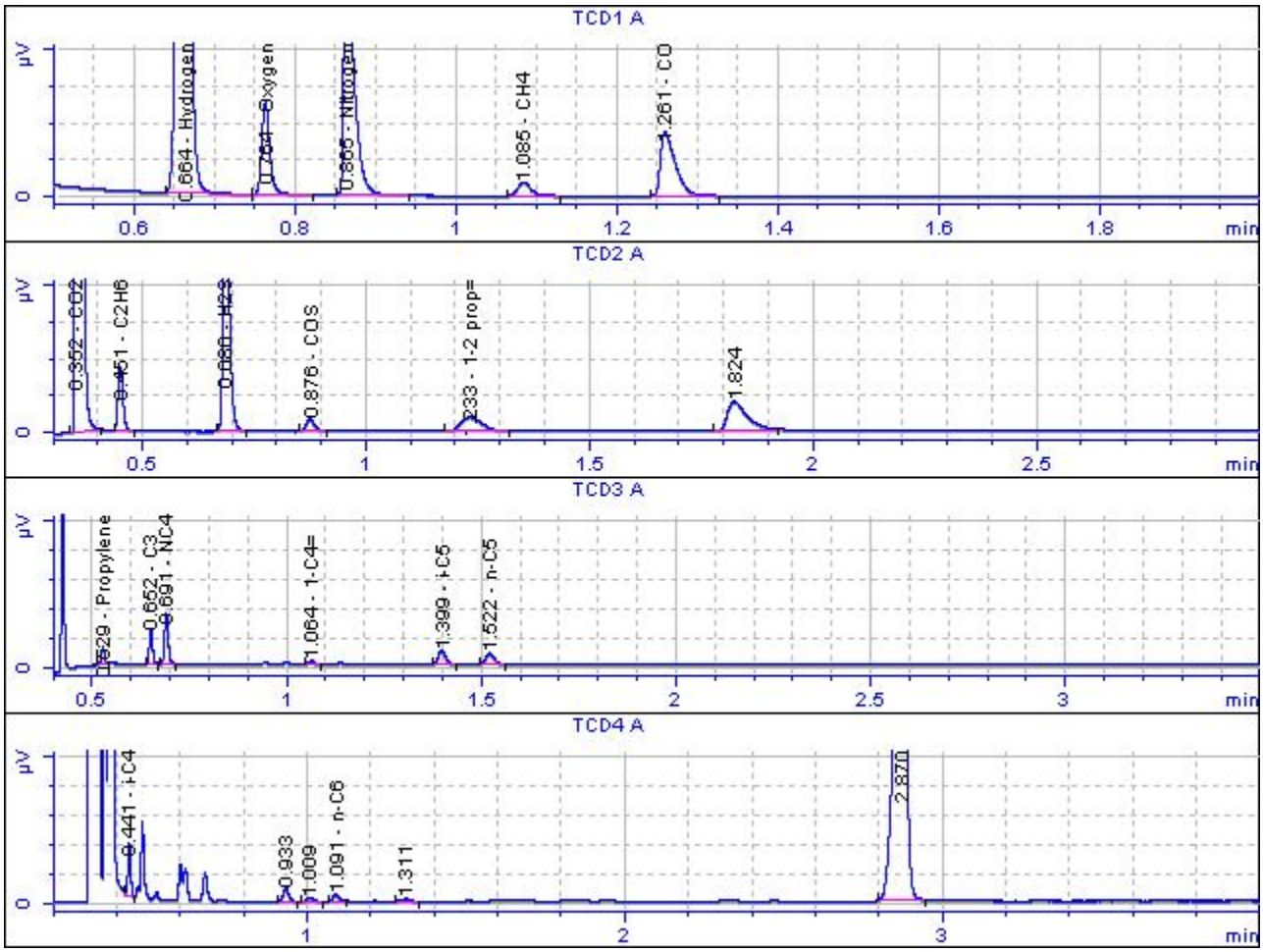
```
Total amount = 100.25229
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO60CO, 60min
Sample note:	60 CO in lagre reactor at time =60
Submission time:	Tuesday, May 19, 2009 1:33:03 PM
Operator:	Aziz
Injection date:	Tuesday, May 19, 2009 1:33:53 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.664	BP	1.5683e+005	1.05208e-004	16.478708	Hydrogen
1	0.764	VB	8813.57071	1.06315e-003	9.358423	Oxygen
1	0.865	BB	3.0164e+004	1.25339e-003	37.759432	Nitrogen
1	1.085	BB	2069.16051	5.00940e-004	1.035231	CH4
1	1.261	BB	1.1212e+004	1.24655e-003	13.958416	CO
2	0.352	PB	2.4930e+005	7.24041e-005	18.027493	CO2
2	0.409		-	-	-	C2H4
2	0.451	PB	6515.84420	6.57906e-005	0.428146	C2H6
2	0.548		-	-	-	C2H2
2	0.686	BB	3.0672e+004	7.69512e-005	2.357325	H2S
2	0.876	BB	2119.45078	6.12584e-005	0.129672	COS
2	1.233	BB	6385.08909	1.85836e-005	0.118510	1-2 prop=
2	1.824	PB	1.2075e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.529	BB	364.59859	9.12409e-005	0.033225	Propylene
3	0.652	BB	680.50244	1.02067e-004	0.069370	C3
3	0.691	BB	1095.62314	7.65293e-005	0.083743	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.064	PP	98.01062	8.30556e-005	0.008130	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.399	BB	609.17934	7.53631e-005	0.045852	i-C5
3	1.522	BB	544.55074	7.49931e-005	0.040787	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.720	BB	342.15789	0.00000e+000	0.000000	
4	0.441	BBA	2273.67092	2.45182e-005	0.055677	i-C4
4	0.933	BP	1077.11950	0.00000e+000	0.000000	

4	1.009	BP	353.34094	0.00000e+000	0.000000	
4	1.091	BB	582.28809	2.03938e-005	0.011860	n-C6
4	1.311	BP	251.30278	0.00000e+000	0.000000	
4	2.870	BB	6.3565e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.664	BP	1.5683e+005	1.05208e-004	16.49930	Hydrogen
1	0.764	VB	8813.57071	1.06315e-003	9.37012	Oxygen
1	0.865	BB	3.0164e+004	1.25339e-003	37.80662	Nitrogen
1	1.085	BB	2069.16051	5.00940e-004	1.03652	CH4
1	1.261	BB	1.1212e+004	1.24655e-003	13.97586	CO
2	0.352	PB	2.4930e+005	7.24041e-005	18.05002	CO2
2	0.409		-	-	-	C2H4
2	0.451	PB	6515.84420	6.57906e-005	0.42868	C2H6
2	0.548		-	-	-	C2H2
2	0.686	BB	3.0672e+004	7.69512e-005	2.36027	H2S
2	0.876	BB	2119.45078	6.12584e-005	0.12983	COS
2	1.233	BB	6385.08909	1.85836e-005	0.11866	1-2 prop=
2	1.824	PB	1.2075e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.529	BB	364.59859	9.12409e-005	0.03327	Propylene
3	0.652	BB	680.50244	1.02067e-004	0.06946	C3
3	0.691	BB	1095.62314	7.65293e-005	0.08385	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.064	PP	98.01062	8.30556e-005	0.00814	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.399	BB	609.17934	7.53631e-005	0.04591	i-C5
3	1.522	BB	544.55074	7.49931e-005	0.04084	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.720	BB	342.15789	0.00000e+000	0.00000	
4	0.441	BBA	2273.67092	2.45182e-005	0.05575	i-C4
4	0.933	BP	1077.11950	0.00000e+000	0.00000	

4	1.009	BP	353.34094	0.00000e+000	0.00000	
4	1.091	BB	582.28809	2.03938e-005	0.01188	n-C6
4	1.311	BP	251.30278	0.00000e+000	0.00000	
4	2.870	BB	6.3565e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

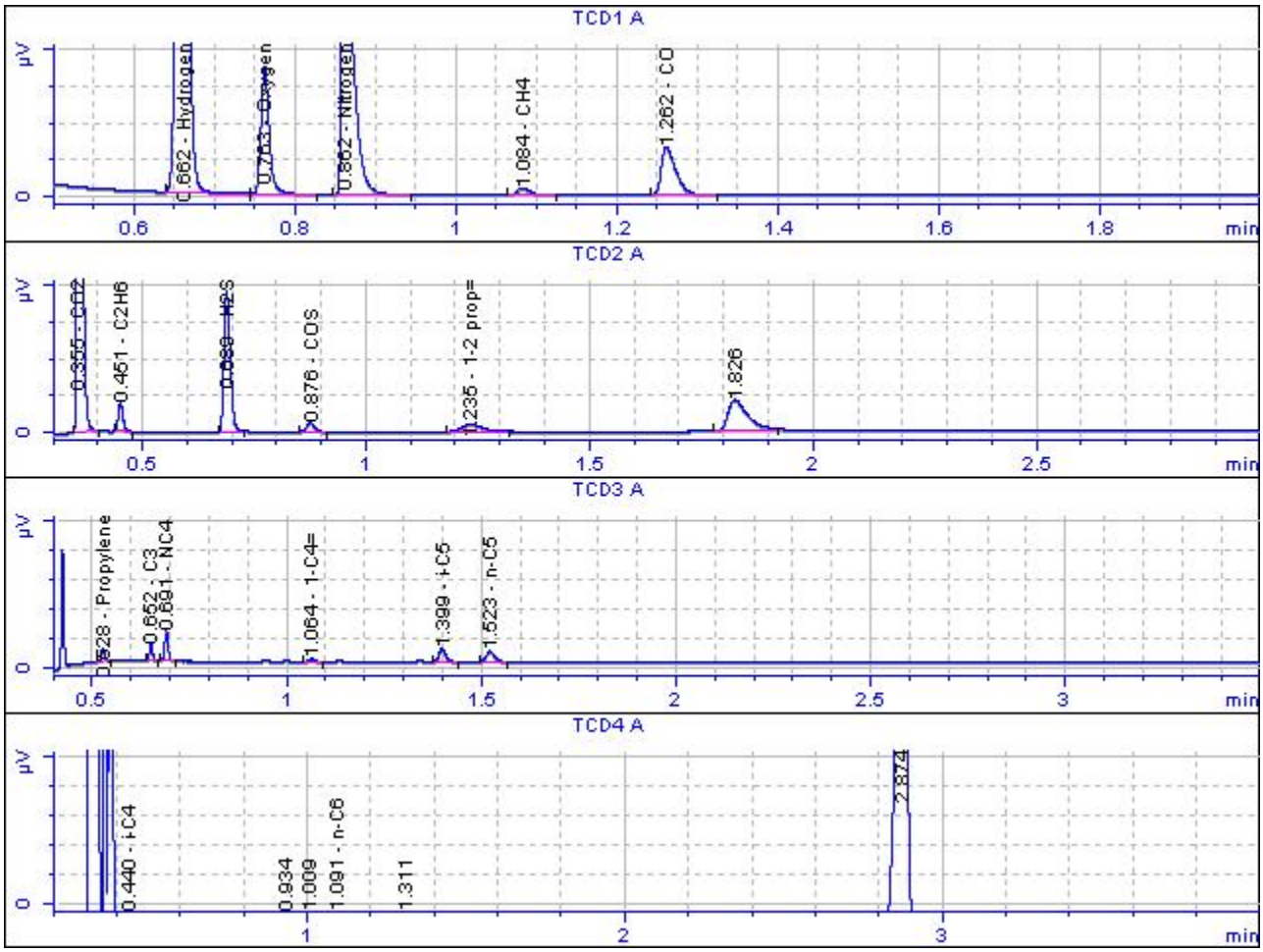
```
Total amount = 100.12496
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO60CO, 30min
Sample note:	60 CO in lagre reactor at time =30
Submission time:	Tuesday, May 19, 2009 1:02:41 PM
Operator:	Aziz
Injection date:	Tuesday, May 19, 2009 1:03:29 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.662	BP	1.0316e+005	1.05208e-004	10.977052	Hydrogen
1	0.763	VP	1.2202e+004	1.06315e-003	13.120592	Oxygen
1	0.862	BB	4.1255e+004	1.25339e-003	52.298138	Nitrogen
1	1.084	BB	986.42680	5.00940e-004	0.499770	CH4
1	1.262	BB	8219.33601	1.24655e-003	10.362513	CO
2	0.355	PB	1.4588e+005	7.24041e-005	10.682798	CO2
2	0.409		-	-	-	C2H4
2	0.451	PB	2908.83502	6.57906e-005	0.193554	C2H6
2	0.548		-	-	-	C2H2
2	0.689	BB	1.8823e+004	7.69512e-005	1.464980	H2S
2	0.876	BB	1537.57989	6.12584e-005	0.095263	COS
2	1.235	PB	2976.47128	1.85836e-005	0.055944	1-2 prop=
2	1.826	PB	1.2808e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.528	BB	304.67676	9.12409e-005	0.028116	Propylene
3	0.652	BB	335.39890	1.02067e-004	0.034623	C3
3	0.691	PB	666.79811	7.65293e-005	0.051611	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.064	PP	82.18311	8.30556e-005	0.006904	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.399	PB	551.30507	7.53631e-005	0.042021	i-C5
3	1.523	BB	513.38362	7.49931e-005	0.038939	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.720	BB	317.35140	0.00000e+000	0.000000	
4	0.440	BBA	1401.90582	2.45182e-005	0.034764	i-C4
4	0.934	BP	1117.44397	0.00000e+000	0.000000	

4	1.009	BP	372.03767	0.00000e+000	0.000000	
4	1.091	BB	602.22902	2.03938e-005	0.012422	n-C6
4	1.311	BP	264.15494	0.00000e+000	0.000000	
4	2.874	BB	7.4190e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.662	BP	1.0316e+005	1.05208e-004	10.85341	Hydrogen
1	0.763	VP	1.2202e+004	1.06315e-003	12.97281	Oxygen
1	0.862	BB	4.1255e+004	1.25339e-003	51.70907	Nitrogen
1	1.084	BB	986.42680	5.00940e-004	0.49414	CH4
1	1.262	BB	8219.33601	1.24655e-003	10.24579	CO
2	0.355	PB	1.4588e+005	7.24041e-005	10.56247	CO2
2	0.409		-	-	-	C2H4
2	0.451	PB	2908.83502	6.57906e-005	0.19137	C2H6
2	0.548		-	-	-	C2H2
2	0.689	BB	1.8823e+004	7.69512e-005	1.44848	H2S
2	0.876	BB	1537.57989	6.12584e-005	0.09419	COS
2	1.235	PB	2976.47128	1.85836e-005	0.05531	1-2 prop=
2	1.826	PB	1.2808e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.528	BB	304.67676	9.12409e-005	0.02780	Propylene
3	0.652	BB	335.39890	1.02067e-004	0.03423	C3
3	0.691	PB	666.79811	7.65293e-005	0.05103	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.064	PP	82.18311	8.30556e-005	0.00683	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.399	PB	551.30507	7.53631e-005	0.04155	i-C5
3	1.523	BB	513.38362	7.49931e-005	0.03850	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.720	BB	317.35140	0.00000e+000	0.00000	
4	0.440	BBA	1401.90582	2.45182e-005	0.03437	i-C4
4	0.934	BP	1117.44397	0.00000e+000	0.00000	

4	1.009	BP	372.03767	0.00000e+000	0.00000	
4	1.091	BB	602.22902	2.03938e-005	0.01228	n-C6
4	1.311	BP	264.15494	0.00000e+000	0.00000	
4	2.874	BB	7.4190e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

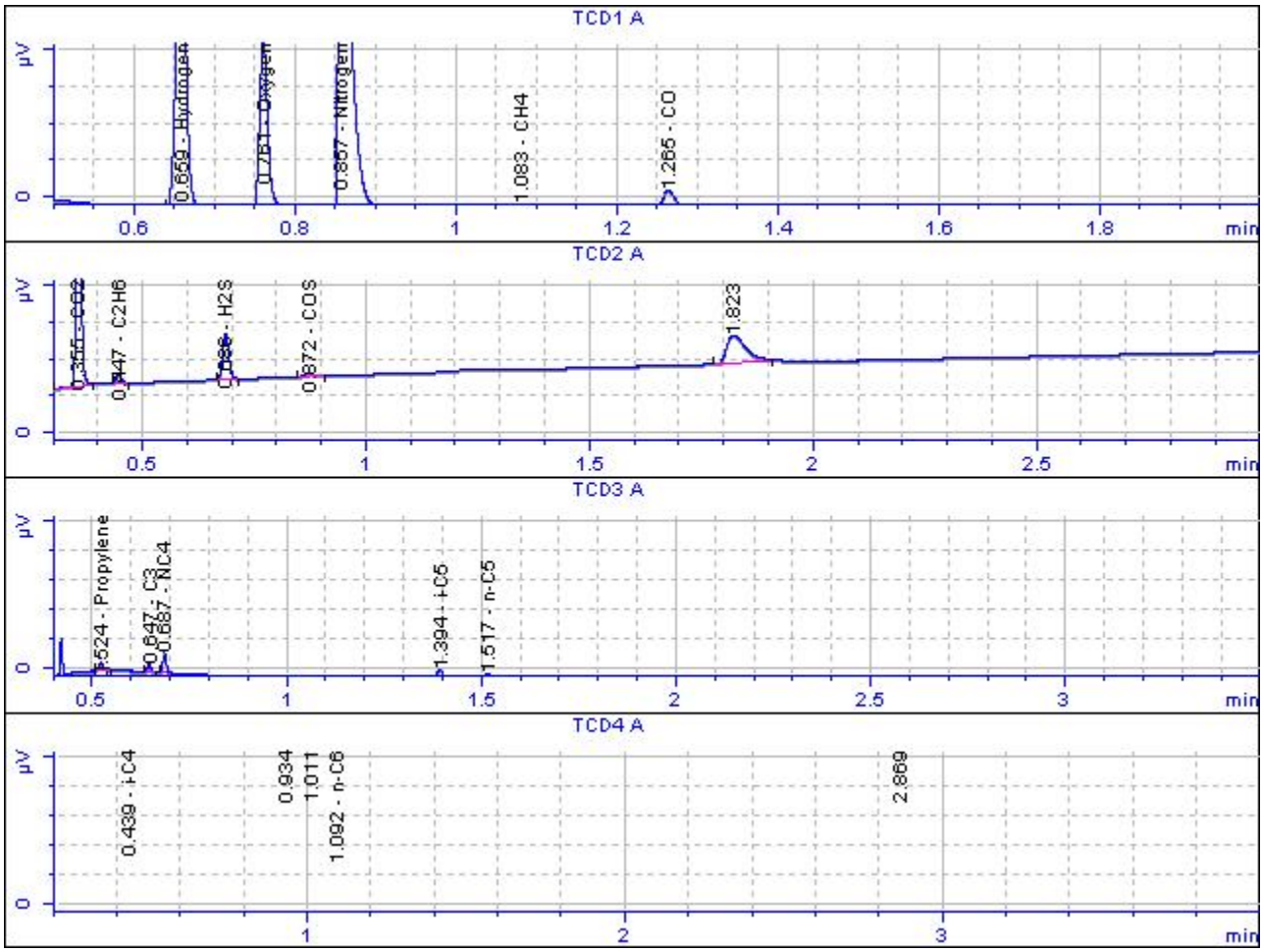
```
Total amount = 98.87364
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO60CO, 0min
Sample note:	60 CO in lagre reactor at time =0
Submission time:	Tuesday, May 19, 2009 12:36:54 PM
Operator:	Aziz
Injection date:	Tuesday, May 19, 2009 12:38:02 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.659	BP	3.7050e+004	1.05208e-004	3.812486	Hydrogen
1	0.761	BP	1.6897e+004	1.06315e-003	17.570025	Oxygen
1	0.857	BB	5.6845e+004	1.25339e-003	69.686381	Nitrogen
1	1.083	PB	249.81166	5.00940e-004	0.122397	CH4
1	1.265	BB	3585.23631	1.24655e-003	4.371197	CO
2	0.355	PB	5.1560e+004	7.24041e-005	3.651293	CO2
2	0.409		-	-	-	C2H4
2	0.447	PP	851.85434	6.57906e-005	0.054815	C2H6
2	0.548		-	-	-	C2H2
2	0.686	BB	5946.40638	7.69512e-005	0.447552	H2S
2	0.872	BB	713.75539	6.12584e-005	0.042765	COS
2	1.218		-	-	-	1-2 prop=
2	1.823	PB	1.1442e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	260.87653	9.12409e-005	0.023281	Propylene
3	0.647	PP	157.28371	1.02067e-004	0.015702	C3
3	0.687	BB	420.70463	7.65293e-005	0.031490	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.394	PB	618.37040	7.53631e-005	0.045581	i-C5
3	1.517	BB	568.53514	7.49931e-005	0.041702	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.716	BB	352.21085	0.00000e+000	0.000000	
4	0.439	BBA	613.21132	2.45182e-005	0.014705	i-C4
4	0.934	BV	2805.94173	0.00000e+000	0.000000	

4	1.011	VV	2150.36125	0.00000e+000	0.000000	
4	1.092	VV	3440.55412	2.03938e-005	0.068628	n-C6
4	2.869	VV	1.6466e+005	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.659	BP	3.7050e+004	1.05208e-004	3.89793	Hydrogen
1	0.761	BP	1.6897e+004	1.06315e-003	17.96382	Oxygen
1	0.857	BB	5.6845e+004	1.25339e-003	71.24824	Nitrogen
1	1.083	PB	249.81166	5.00940e-004	0.12514	CH4
1	1.265	BB	3585.23631	1.24655e-003	4.46917	CO
2	0.355	PB	5.1560e+004	7.24041e-005	3.73313	CO2
2	0.409		-	-	-	C2H4
2	0.447	PP	851.85434	6.57906e-005	0.05604	C2H6
2	0.548		-	-	-	C2H2
2	0.686	BB	5946.40638	7.69512e-005	0.45758	H2S
2	0.872	BB	713.75539	6.12584e-005	0.04372	COS
2	1.218		-	-	-	1-2 prop=
2	1.823	PB	1.1442e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	260.87653	9.12409e-005	0.02380	Propylene
3	0.647	PP	157.28371	1.02067e-004	0.01605	C3
3	0.687	BB	420.70463	7.65293e-005	0.03220	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.394	PB	618.37040	7.53631e-005	0.04660	i-C5
3	1.517	BB	568.53514	7.49931e-005	0.04264	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.716	BB	352.21085	0.00000e+000	0.00000	
4	0.439	BBA	613.21132	2.45182e-005	0.01503	i-C4
4	0.934	BV	2805.94173	0.00000e+000	0.00000	

4	1.011	VV	2150.36125	0.00000e+000	0.00000	
4	1.092	VV	3440.55412	2.03938e-005	0.07017	n-C6
4	2.869	VV	1.6466e+005	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

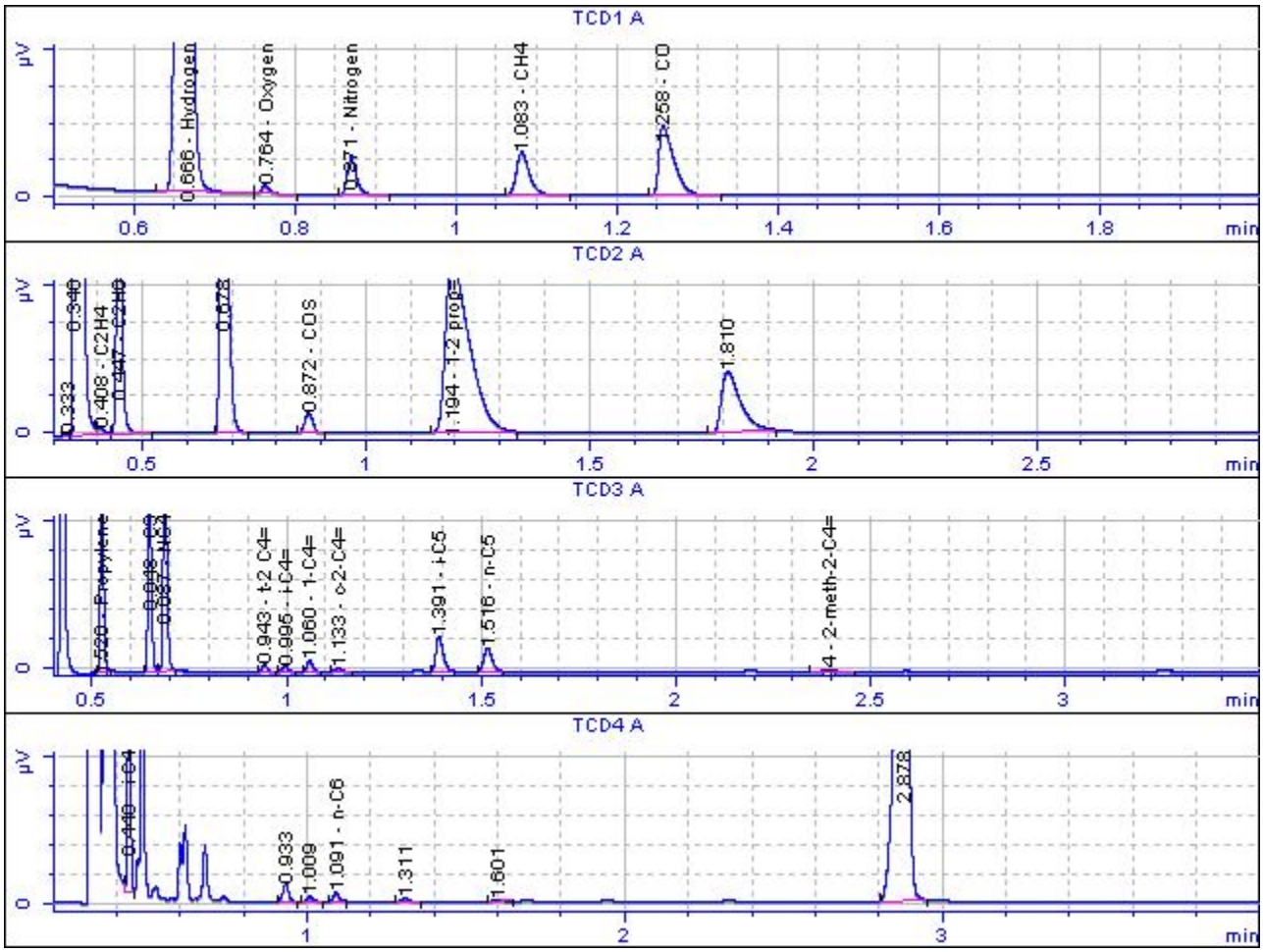
```
Total amount = 102.24128
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO30COL, 90min
Sample note:	30 CO in lagre reactor at time =90
Submission time:	Thursday, May 21, 2009 1:59:52 PM
Operator:	Aziz
Injection date:	Thursday, May 21, 2009 2:00:47 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.666	BV	2.9338e+005	1.05208e-004	50.040767	Hydrogen
1	0.764	VP	774.67690	1.06315e-003	1.335237	Oxygen
1	0.871	BB	4098.14665	1.25339e-003	8.327546	Nitrogen
1	1.083	BB	6739.57768	5.00940e-004	5.473471	CH4
1	1.258	BB	1.2396e+004	1.24655e-003	25.052009	CO
2	0.333	PP	95.09487	0.00000e+000	0.000000	
2	0.346	VV	4.6708e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.408	VV	1054.61071	7.03854e-005	0.120343	C2H4
2	0.447	VB	3.4395e+004	6.57906e-005	3.668581	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	7.4531e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.872	BB	3540.52424	6.12584e-005	0.351623	COS
2	1.194	PB	8.7591e+004	1.85836e-005	2.638960	1-2 prop=
2	1.810	PB	2.4985e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.526	BB	4659.14731	9.12409e-005	0.689193	Propylene
3	0.648	PV	4143.62537	1.02067e-004	0.685661	C3
3	0.687	VB	5504.31552	7.65293e-005	0.682929	NC4
3	0.943	BP	223.04665	8.11249e-005	0.029336	t-2 C4=
3	0.995	BB	194.00792	8.13163e-005	0.025577	i-C4=
3	1.060	BB	366.00167	8.30556e-005	0.049283	1-C4=
3	1.133	PP	137.68063	8.29864e-005	0.018524	c-2-C4=
3	1.391	BB	1558.58000	7.53631e-005	0.190429	i-C5
3	1.516	BB	1172.22854	7.49931e-005	0.142521	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.394	PP	102.67809	7.78266e-005	0.012955	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.704	BB	537.81833	0.00000e+000	0.000000	
4	0.440	BBA	1.1064e+004	2.45182e-005	0.439778	i-C4
4	0.933	BP	1505.88048	0.00000e+000	0.000000	
4	1.009	BP	480.10017	0.00000e+000	0.000000	
4	1.091	BB	764.55197	2.03938e-005	0.025278	n-C6
4	1.311	BP	319.36868	0.00000e+000	0.000000	
4	1.601	PB	189.50811	0.00000e+000	0.000000	
4	2.878	BB	8.5604e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.666	BV	2.9338e+005	1.05208e-004	30.86592	Hydrogen
1	0.764	VP	774.67690	1.06315e-003	0.82360	Oxygen
1	0.871	BB	4098.14665	1.25339e-003	5.13656	Nitrogen
1	1.083	BB	6739.57768	5.00940e-004	3.37612	CH4
1	1.258	BB	1.2396e+004	1.24655e-003	15.45247	CO
2	0.333	PP	95.09487	0.00000e+000	0.00000	
2	0.346	VV	4.6708e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.408	VV	1054.61071	7.03854e-005	0.07423	C2H4
2	0.447	VB	3.4395e+004	6.57906e-005	2.26284	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	7.4531e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.872	BB	3540.52424	6.12584e-005	0.21689	COS
2	1.194	PB	8.7591e+004	1.85836e-005	1.62775	1-2 prop=
2	1.810	PB	2.4985e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.526	BB	4659.14731	9.12409e-005	0.42510	Propylene
3	0.648	PV	4143.62537	1.02067e-004	0.42293	C3
3	0.687	VB	5504.31552	7.65293e-005	0.42124	NC4
3	0.943	BP	223.04665	8.11249e-005	0.01809	t-2 C4=
3	0.995	BB	194.00792	8.13163e-005	0.01578	i-C4=
3	1.060	BB	366.00167	8.30556e-005	0.03040	1-C4=
3	1.133	PP	137.68063	8.29864e-005	0.01143	c-2-C4=
3	1.391	BB	1558.58000	7.53631e-005	0.11746	i-C5
3	1.516	BB	1172.22854	7.49931e-005	0.08791	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.394	PP	102.67809	7.78266e-005	0.00799	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.704	BB	537.81833	0.00000e+000	0.00000	
4	0.440	BBA	1.1064e+004	2.45182e-005	0.27126	i-C4
4	0.933	BP	1505.88048	0.00000e+000	0.00000	
4	1.009	BP	480.10017	0.00000e+000	0.00000	
4	1.091	BB	764.55197	2.03938e-005	0.01559	n-C6
4	1.311	BP	319.36868	0.00000e+000	0.00000	
4	1.601	PB	189.50811	0.00000e+000	0.00000	
4	2.878	BB	8.5604e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

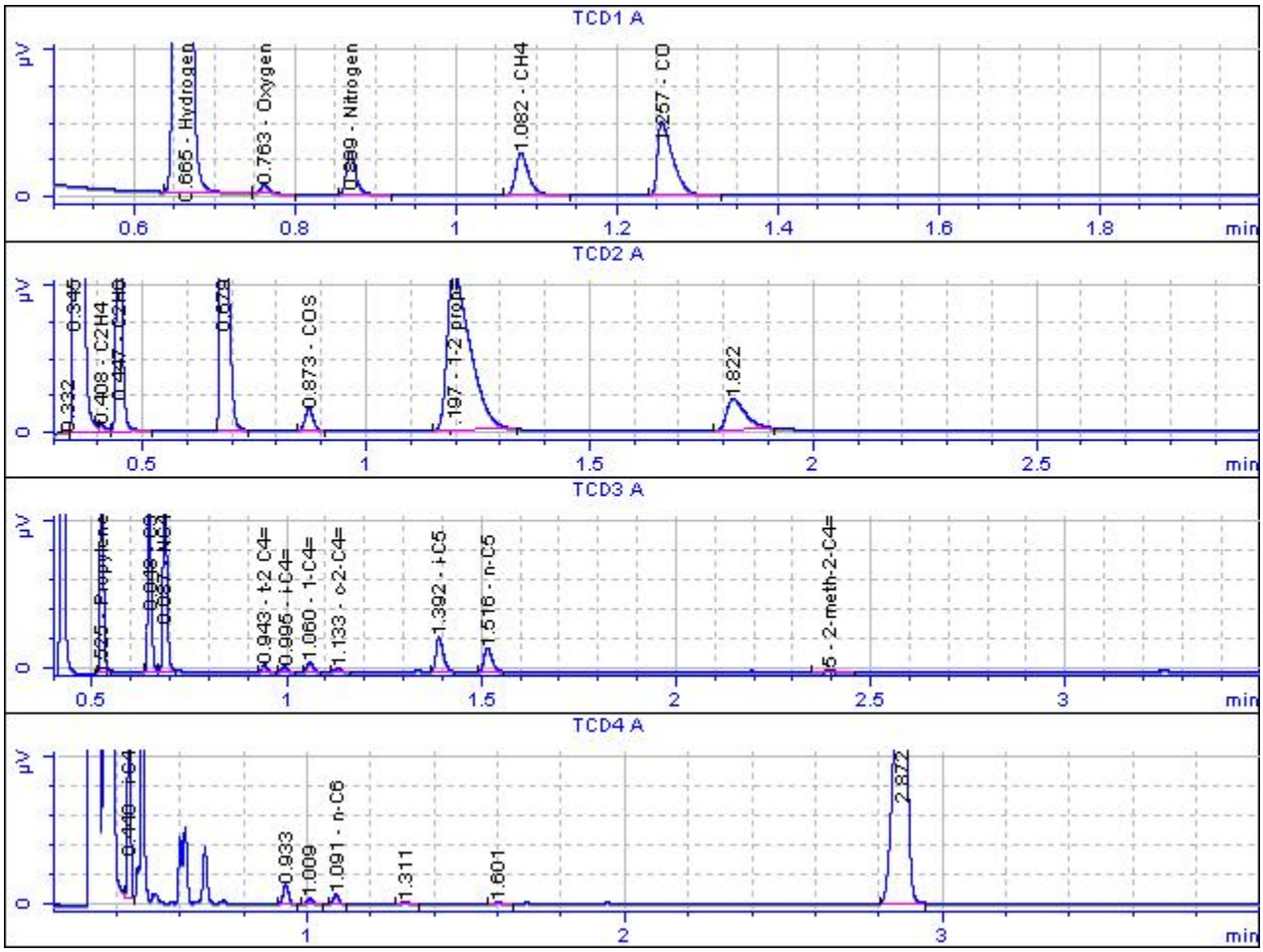
```
Total amount = 61.68156
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO30COL, 60min
Sample note:	30 CO in lagre reactor at time =60
Submission time:	Thursday, May 21, 2009 1:32:43 PM
Operator:	Aziz
Injection date:	Thursday, May 21, 2009 1:33:46 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.665	BV	2.8549e+005	1.05208e-004	47.879325	Hydrogen
1	0.763	VP	847.31297	1.06315e-003	1.435951	Oxygen
1	0.869	BB	4910.77193	1.25339e-003	9.811540	Nitrogen
1	1.082	BB	6565.76327	5.00940e-004	5.242920	CH4
1	1.257	BB	1.3219e+004	1.24655e-003	26.266809	CO
2	0.332	PP	91.49679	0.00000e+000	0.000000	
2	0.345	VV	5.0207e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.408	VV	1040.52706	7.03854e-005	0.116745	C2H4
2	0.447	VB	3.4083e+004	6.57906e-005	3.574362	C2H6
2	0.548		-	-	-	C2H2
2	0.679	BB	6.6100e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.873	BB	3926.89636	6.12584e-005	0.383458	COS
2	1.197	BB	7.7995e+004	1.85836e-005	2.310452	1-2 prop=
2	1.822	PB	1.2711e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	5406.06134	9.12409e-005	0.786272	Propylene
3	0.648	BV	3988.74193	1.02067e-004	0.648967	C3
3	0.687	VB	5314.41479	7.65293e-005	0.648314	NC4
3	0.943	BP	199.38721	8.11249e-005	0.025784	t-2 C4=
3	0.995	BB	178.89222	8.13163e-005	0.023188	i-C4=
3	1.060	BB	338.97312	8.30556e-005	0.044878	1-C4=
3	1.133	BP	123.60605	8.29864e-005	0.016351	c-2-C4=
3	1.392	BB	1535.30624	7.53631e-005	0.184440	i-C5
3	1.516	BB	1180.39900	7.49931e-005	0.141108	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.395	BP	86.27399	7.78266e-005	0.010703	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.705	BB	564.88563	0.00000e+000	0.000000	
4	0.440	BBA	1.0768e+004	2.45182e-005	0.420832	i-C4
4	0.933	BP	1652.10333	0.00000e+000	0.000000	
4	1.009	BP	533.55433	0.00000e+000	0.000000	
4	1.091	BB	848.99168	2.03938e-005	0.027600	n-C6
4	1.311	BB	341.49958	0.00000e+000	0.000000	
4	1.601	PB	201.54682	0.00000e+000	0.000000	
4	2.872	BB	6.4103e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.665	BV	2.8549e+005	1.05208e-004	30.03624	Hydrogen
1	0.763	VP	847.31297	1.06315e-003	0.90082	Oxygen
1	0.869	BB	4910.77193	1.25339e-003	6.15509	Nitrogen
1	1.082	BB	6565.76327	5.00940e-004	3.28905	CH4
1	1.257	BB	1.3219e+004	1.24655e-003	16.47801	CO
2	0.332	PP	91.49679	0.00000e+000	0.00000	
2	0.345	VV	5.0207e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.408	VV	1040.52706	7.03854e-005	0.07324	C2H4
2	0.447	VB	3.4083e+004	6.57906e-005	2.24231	C2H6
2	0.548		-	-	-	C2H2
2	0.679	BB	6.6100e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.873	BB	3926.89636	6.12584e-005	0.24056	COS
2	1.197	BB	7.7995e+004	1.85836e-005	1.44942	1-2 prop=
2	1.822	PB	1.2711e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	5406.06134	9.12409e-005	0.49325	Propylene
3	0.648	BV	3988.74193	1.02067e-004	0.40712	C3
3	0.687	VB	5314.41479	7.65293e-005	0.40671	NC4
3	0.943	BP	199.38721	8.11249e-005	0.01618	t-2 C4=
3	0.995	BB	178.89222	8.13163e-005	0.01455	i-C4=
3	1.060	BB	338.97312	8.30556e-005	0.02815	1-C4=
3	1.133	BP	123.60605	8.29864e-005	0.01026	c-2-C4=
3	1.392	BB	1535.30624	7.53631e-005	0.11571	i-C5
3	1.516	BB	1180.39900	7.49931e-005	0.08852	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.395	BP	86.27399	7.78266e-005	0.00671	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.705	BB	564.88563	0.00000e+000	0.00000	
4	0.440	BBA	1.0768e+004	2.45182e-005	0.26400	i-C4
4	0.933	BP	1652.10333	0.00000e+000	0.00000	
4	1.009	BP	533.55433	0.00000e+000	0.00000	
4	1.091	BB	848.99168	2.03938e-005	0.01731	n-C6
4	1.311	BB	341.49958	0.00000e+000	0.00000	
4	1.601	PB	201.54682	0.00000e+000	0.00000	
4	2.872	BB	6.4103e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

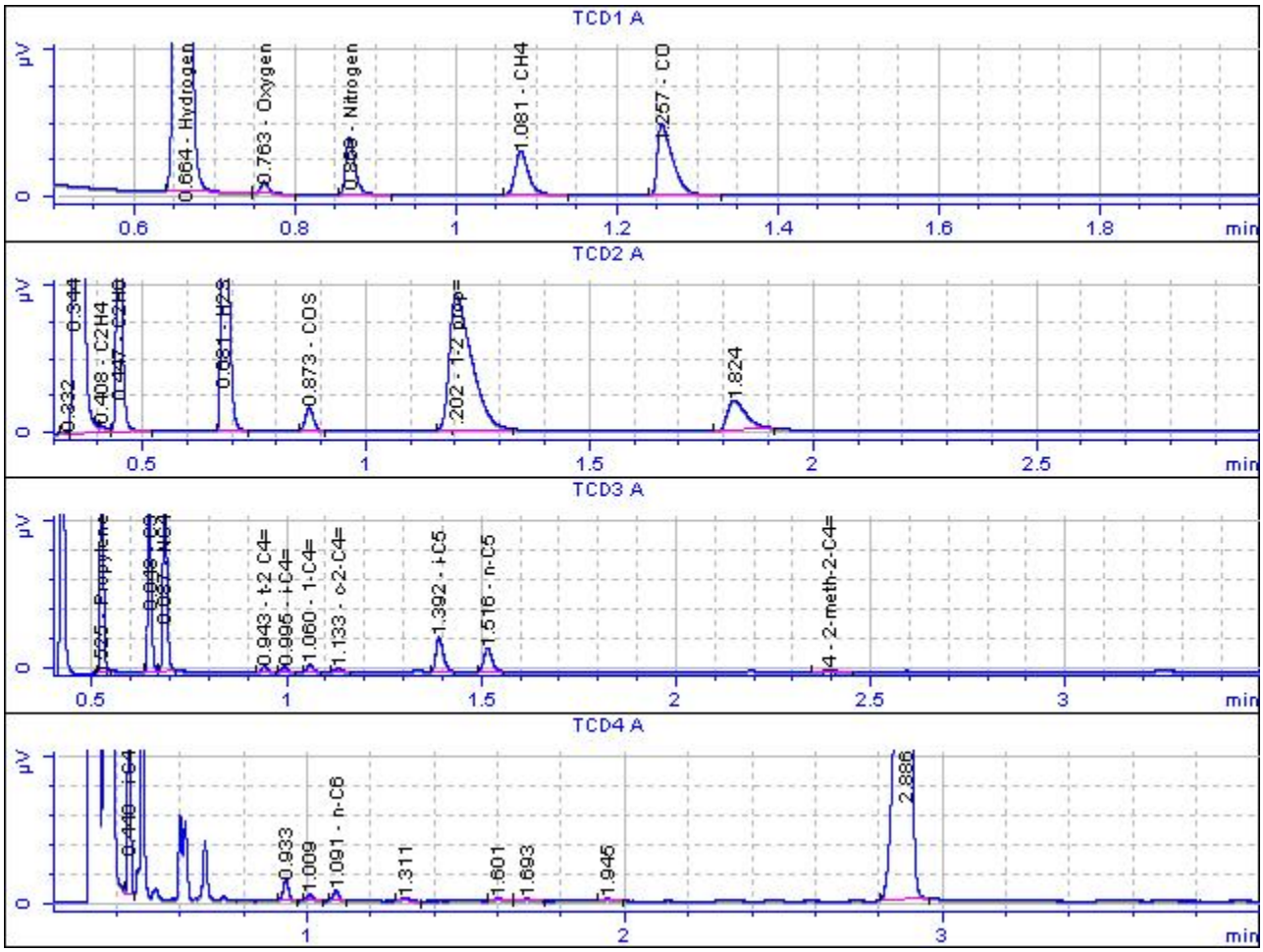
```
Total amount = 62.73321
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO30COL, 30min
Sample note:	30 CO in lagre reactor at time =30
Submission time:	Thursday, May 21, 2009 12:59:22 PM
Operator:	Aziz
Injection date:	Thursday, May 21, 2009 1:00:16 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.664	BP	2.5544e+005	1.05208e-004	41.140361	Hydrogen
1	0.763	VP	1126.31905	1.06315e-003	1.833063	Oxygen
1	0.869	BB	6339.73799	1.25339e-003	12.164075	Nitrogen
1	1.081	BB	6908.01765	5.00940e-004	5.297389	CH4
1	1.257	BB	1.2790e+004	1.24655e-003	24.406240	CO
2	0.332	PP	112.35641	0.00000e+000	0.000000	
2	0.344	VV	5.3599e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.408	VV	1035.11453	7.03854e-005	0.111530	C2H4
2	0.447	VB	3.5400e+004	6.57906e-005	3.565216	C2H6
2	0.548		-	-	-	C2H2
2	0.681	BB	5.4822e+004	7.69512e-005	6.457976	H2S
2	0.873	BB	4073.25241	6.12584e-005	0.381970	COS
2	1.202	BB	6.4470e+004	1.85836e-005	1.834053	1-2 prop=
2	1.824	PB	1.2252e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	5422.74469	9.12409e-005	0.757411	Propylene
3	0.648	BV	3936.10540	1.02067e-004	0.614998	C3
3	0.687	VB	5067.69761	7.65293e-005	0.593692	NC4
3	0.943	BB	163.86721	8.11249e-005	0.020350	t-2 C4=
3	0.995	BP	146.84907	8.13163e-005	0.018280	i-C4=
3	1.060	BB	269.19140	8.30556e-005	0.034226	1-C4=
3	1.133	BP	101.53364	8.29864e-005	0.012899	c-2-C4=
3	1.392	BB	1518.31488	7.53631e-005	0.175163	i-C5
3	1.516	BB	1163.05447	7.49931e-005	0.133519	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.394	PB	81.44261	7.78266e-005	0.009703	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.704	BB	550.12507	0.00000e+000	0.000000	

4	0.440	BBA	1.0916e+004	2.45182e-005	0.409727	i-C4
4	0.933	BP	1717.78499	0.00000e+000	0.000000	
4	1.009	BP	560.53193	0.00000e+000	0.000000	
4	1.091	BB	901.90588	2.03938e-005	0.028157	n-C6
4	1.311	BP	377.09427	0.00000e+000	0.000000	
4	1.601	PB	374.09301	0.00000e+000	0.000000	
4	1.693	BB	311.84115	0.00000e+000	0.000000	
4	1.945	PB	287.77010	0.00000e+000	0.000000	
4	2.886	BB	1.1429e+005	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.664	BP	2.5544e+005	1.05208e-004	26.87480	Hydrogen
1	0.763	VP	1126.31905	1.06315e-003	1.19744	Oxygen
1	0.869	BB	6339.73799	1.25339e-003	7.94614	Nitrogen
1	1.081	BB	6908.01765	5.00940e-004	3.46050	CH4
1	1.257	BB	1.2790e+004	1.24655e-003	15.94329	CO
2	0.332	PP	112.35641	0.00000e+000	0.00000	
2	0.344	VV	5.3599e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.408	VV	1035.11453	7.03854e-005	0.07286	C2H4
2	0.447	VB	3.5400e+004	6.57906e-005	2.32897	C2H6
2	0.548		-	-	-	C2H2
2	0.681	BB	5.4822e+004	7.69512e-005	4.21865	H2S
2	0.873	BB	4073.25241	6.12584e-005	0.24952	COS
2	1.202	BB	6.4470e+004	1.85836e-005	1.19809	1-2 prop=
2	1.824	PB	1.2252e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	5422.74469	9.12409e-005	0.49478	Propylene
3	0.648	BV	3936.10540	1.02067e-004	0.40175	C3
3	0.687	VB	5067.69761	7.65293e-005	0.38783	NC4
3	0.943	BB	163.86721	8.11249e-005	0.01329	t-2 C4=
3	0.995	BP	146.84907	8.13163e-005	0.01194	i-C4=
3	1.060	BB	269.19140	8.30556e-005	0.02236	1-C4=
3	1.133	BP	101.53364	8.29864e-005	0.00843	c-2-C4=
3	1.392	BB	1518.31488	7.53631e-005	0.11442	i-C5
3	1.516	BB	1163.05447	7.49931e-005	0.08722	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.394	PB	81.44261	7.78266e-005	0.00634	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.704	BB	550.12507	0.00000e+000	0.00000	

4	0.440	BBA	1.0916e+004	2.45182e-005	0.26765	i-C4
4	0.933	BP	1717.78499	0.00000e+000	0.00000	
4	1.009	BP	560.53193	0.00000e+000	0.00000	
4	1.091	BB	901.90588	2.03938e-005	0.01839	n-C6
4	1.311	BP	377.09427	0.00000e+000	0.00000	
4	1.601	PB	374.09301	0.00000e+000	0.00000	
4	1.693	BB	311.84115	0.00000e+000	0.00000	
4	1.945	PB	287.77010	0.00000e+000	0.00000	
4	2.886	BB	1.1429e+005	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

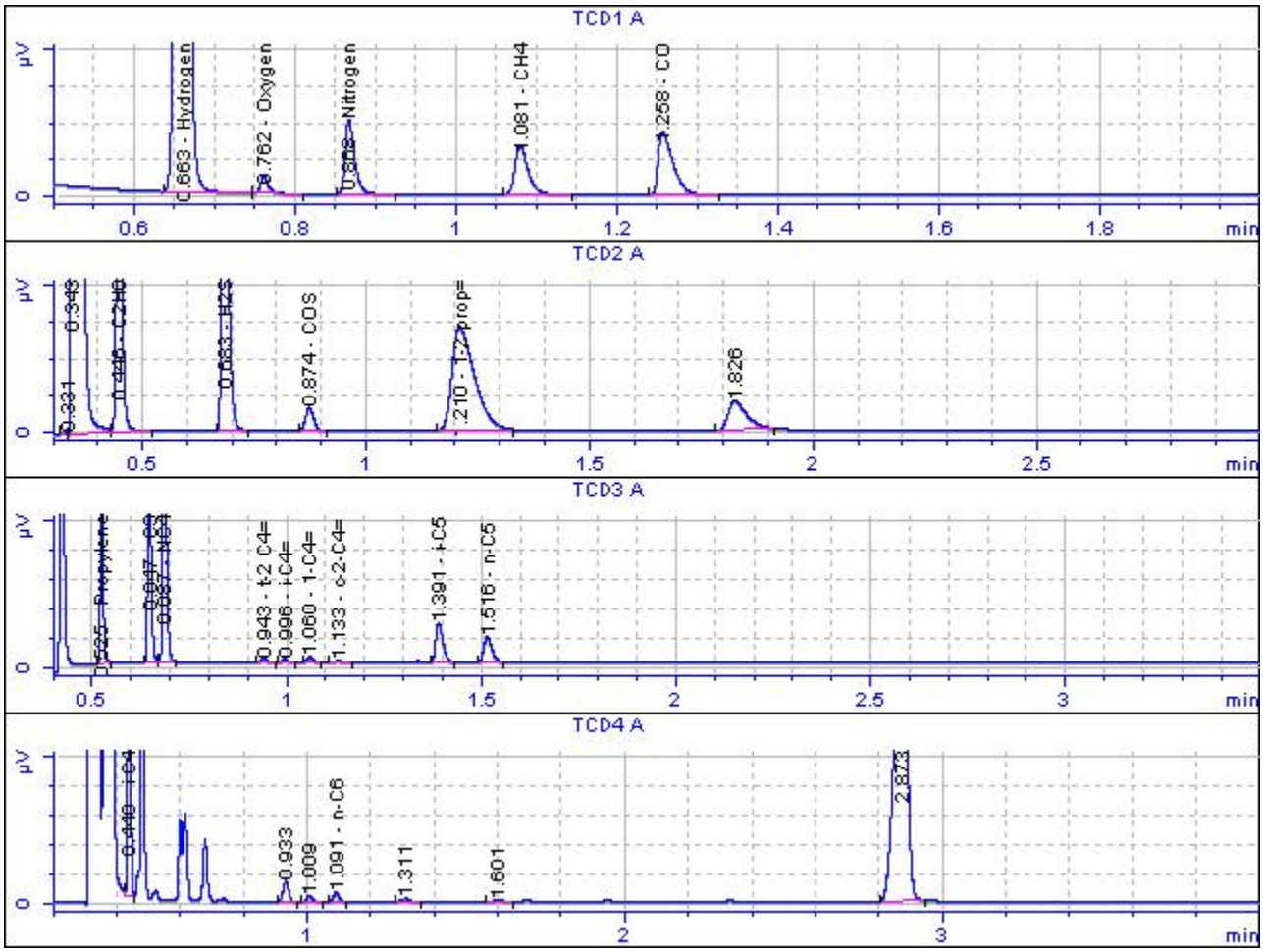
```
Total amount = 65.32465
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO30COL, 0min
Sample note:	30 CO in lagre reactor at time =0
Submission time:	Thursday, May 21, 2009 12:34:57 PM
Operator:	Aziz
Injection date:	Thursday, May 21, 2009 12:35:47 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.663	BP	2.1754e+005	1.05208e-004	36.972338	Hydrogen
1	0.762	VP	1615.00383	1.06315e-003	2.773627	Oxygen
1	0.868	BB	8398.83305	1.25339e-003	17.005336	Nitrogen
1	1.081	BB	7877.96175	5.00940e-004	6.375008	CH4
1	1.258	BB	1.1107e+004	1.24655e-003	22.365079	CO
2	0.331	PP	105.53068	0.00000e+000	0.000000	
2	0.343	VV	5.9006e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.446	VB	3.9002e+004	6.57906e-005	4.145047	C2H6
2	0.548		-	-	-	C2H2
2	0.683	BB	4.5070e+004	7.69512e-005	5.602587	H2S
2	0.874	BB	4119.28422	6.12584e-005	0.407632	COS
2	1.210	PB	4.9636e+004	1.85836e-005	1.490070	1-2 prop=
2	1.826	PB	1.1787e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	2884.44670	9.12409e-005	0.425141	Propylene
3	0.647	BV	4544.95512	1.02067e-004	0.749368	C3
3	0.687	VB	5848.91702	7.65293e-005	0.723077	NC4
3	0.943	PB	144.29540	8.11249e-005	0.018910	t-2 C4=
3	0.996	BB	121.41898	8.13163e-005	0.015949	i-C4=
3	1.060	BB	219.53015	8.30556e-005	0.029454	1-C4=
3	1.133	PP	88.70451	8.29864e-005	0.011891	c-2-C4=
3	1.391	BB	1735.55447	7.53631e-005	0.211290	i-C5
3	1.516	BB	1278.10435	7.49931e-005	0.154835	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.705	BB	581.87398	0.00000e+000	0.000000	

4	0.440	BBA	1.2499e+004	2.45182e-005	0.495055	i-C4
4	0.933	BP	1763.53577	0.00000e+000	0.000000	
4	1.009	BP	562.42248	0.00000e+000	0.000000	
4	1.091	BB	859.16308	2.03938e-005	0.028305	n-C6
4	1.311	BP	356.68996	0.00000e+000	0.000000	
4	1.601	PP	204.02869	0.00000e+000	0.000000	
4	2.873	BB	6.3174e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.663	BP	2.1754e+005	1.05208e-004	22.88735	Hydrogen
1	0.762	VP	1615.00383	1.06315e-003	1.71699	Oxygen
1	0.868	BB	8398.83305	1.25339e-003	10.52698	Nitrogen
1	1.081	BB	7877.96175	5.00940e-004	3.94638	CH4
1	1.258	BB	1.1107e+004	1.24655e-003	13.84488	CO
2	0.331	PP	105.53068	0.00000e+000	0.00000	
2	0.343	VV	5.9006e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.446	VB	3.9002e+004	6.57906e-005	2.56595	C2H6
2	0.548		-	-	-	C2H2
2	0.683	BB	4.5070e+004	7.69512e-005	3.46822	H2S
2	0.874	BB	4119.28422	6.12584e-005	0.25234	COS
2	1.210	PB	4.9636e+004	1.85836e-005	0.92241	1-2 prop=
2	1.826	PB	1.1787e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	2884.44670	9.12409e-005	0.26318	Propylene
3	0.647	BV	4544.95512	1.02067e-004	0.46389	C3
3	0.687	VB	5848.91702	7.65293e-005	0.44761	NC4
3	0.943	PB	144.29540	8.11249e-005	0.01171	t-2 C4=
3	0.996	BB	121.41898	8.13163e-005	0.00987	i-C4=
3	1.060	BB	219.53015	8.30556e-005	0.01823	1-C4=
3	1.133	PP	88.70451	8.29864e-005	0.00736	c-2-C4=
3	1.391	BB	1735.55447	7.53631e-005	0.13080	i-C5
3	1.516	BB	1278.10435	7.49931e-005	0.09585	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.705	BB	581.87398	0.00000e+000	0.00000	

4	0.440	BBA	1.2499e+004	2.45182e-005	0.30646	i-C4
4	0.933	BP	1763.53577	0.00000e+000	0.00000	
4	1.009	BP	562.42248	0.00000e+000	0.00000	
4	1.091	BB	859.16308	2.03938e-005	0.01752	n-C6
4	1.311	BP	356.68996	0.00000e+000	0.00000	
4	1.601	PP	204.02869	0.00000e+000	0.00000	
4	2.873	BB	6.3174e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

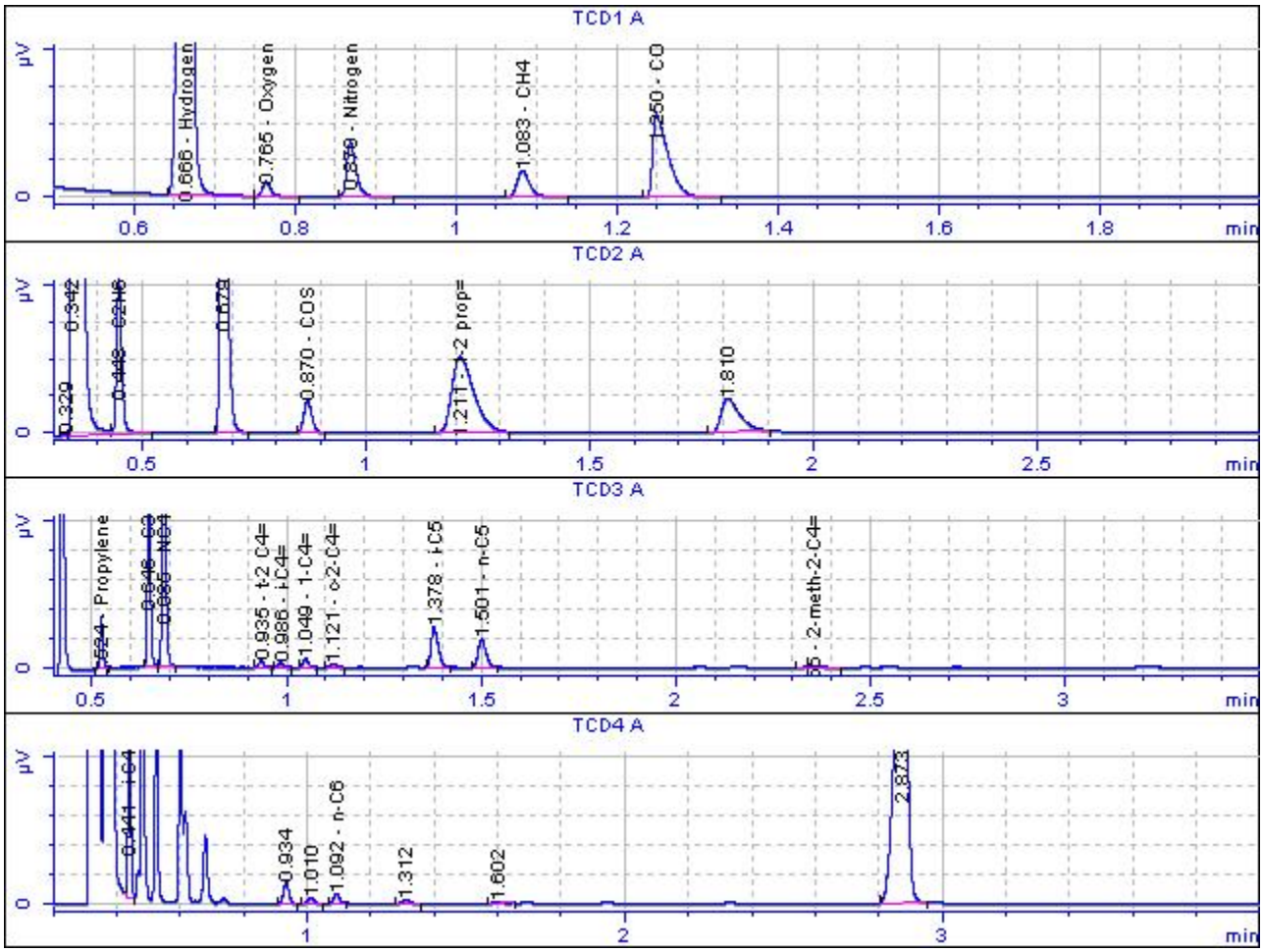
```
Total amount = 61.90399
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100COL, 90min
Sample note:	100 CO in lagre reactor at time =90
Submission time:	Thursday, May 28, 2009 1:04:40 PM
Operator:	Aziz
Injection date:	Thursday, May 28, 2009 1:05:30 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.666	BP	1.6297e+005	1.05208e-004	33.546400	Hydrogen
1	0.765	VP	1408.07320	1.06315e-003	2.928972	Oxygen
1	0.870	BB	6220.54597	1.25339e-003	15.254928	Nitrogen
1	1.083	BB	4171.73203	5.00940e-004	4.088826	CH4
1	1.250	BB	1.5272e+004	1.24655e-003	37.247923	CO
2	0.329	PP	125.34644	0.00000e+000	0.000000	
2	0.342	VB	6.5622e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	1.7738e+004	6.57906e-005	2.283284	C2H6
2	0.548		-	-	-	C2H2
2	0.679	BB	5.7385e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.870	BB	5659.41865	6.12584e-005	0.678319	COS
2	1.211	PB	3.5693e+004	1.85836e-005	1.297806	1-2 prop=
2	1.810	PB	1.3671e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	922.93728	9.12409e-005	0.164763	Propylene
3	0.646	BV	3320.15899	1.02067e-004	0.663040	C3
3	0.685	VB	5139.33334	7.65293e-005	0.769540	NC4
3	0.935	BB	201.04737	8.11249e-005	0.031912	t-2 C4=
3	0.986	PP	150.21233	8.13163e-005	0.023899	i-C4=
3	1.049	BB	282.66446	8.30556e-005	0.045934	1-C4=
3	1.121	BP	127.83301	8.29864e-005	0.020756	c-2-C4=
3	1.378	BB	1726.88827	7.53631e-005	0.254636	i-C5
3	1.501	BB	1356.91834	7.49931e-005	0.199100	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.355	PB	115.28715	7.78266e-005	0.017555	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.649	BB	568.18664	0.00000e+000	0.000000	
4	0.441	BBA	9313.85174	2.45182e-005	0.446802	i-C4
4	0.934	BP	1749.39592	0.00000e+000	0.000000	
4	1.010	BP	556.18196	0.00000e+000	0.000000	
4	1.092	BB	892.29960	2.03938e-005	0.035605	n-C6
4	1.312	BP	348.07777	0.00000e+000	0.000000	
4	1.602	PP	208.87331	0.00000e+000	0.000000	
4	2.873	BB	6.5143e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.666	BP	1.6297e+005	1.05208e-004	17.14546	Hydrogen
1	0.765	VP	1408.07320	1.06315e-003	1.49699	Oxygen
1	0.870	BB	6220.54597	1.25339e-003	7.79675	Nitrogen
1	1.083	BB	4171.73203	5.00940e-004	2.08979	CH4
1	1.250	BB	1.5272e+004	1.24655e-003	19.03730	CO
2	0.329	PP	125.34644	0.00000e+000	0.00000	
2	0.342	VB	6.5622e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	1.7738e+004	6.57906e-005	1.16698	C2H6
2	0.548		-	-	-	C2H2
2	0.679	BB	5.7385e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.870	BB	5659.41865	6.12584e-005	0.34669	COS
2	1.211	PB	3.5693e+004	1.85836e-005	0.66330	1-2 prop=
2	1.810	PB	1.3671e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	922.93728	9.12409e-005	0.08421	Propylene
3	0.646	BV	3320.15899	1.02067e-004	0.33888	C3
3	0.685	VB	5139.33334	7.65293e-005	0.39331	NC4
3	0.935	BB	201.04737	8.11249e-005	0.01631	t-2 C4=
3	0.986	PP	150.21233	8.13163e-005	0.01221	i-C4=
3	1.049	BB	282.66446	8.30556e-005	0.02348	1-C4=
3	1.121	BP	127.83301	8.29864e-005	0.01061	c-2-C4=
3	1.378	BB	1726.88827	7.53631e-005	0.13014	i-C5
3	1.501	BB	1356.91834	7.49931e-005	0.10176	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.355	PB	115.28715	7.78266e-005	0.00897	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.649	BB	568.18664	0.00000e+000	0.00000	
4	0.441	BBA	9313.85174	2.45182e-005	0.22836	i-C4
4	0.934	BP	1749.39592	0.00000e+000	0.00000	
4	1.010	BP	556.18196	0.00000e+000	0.00000	
4	1.092	BB	892.29960	2.03938e-005	0.01820	n-C6
4	1.312	BP	348.07777	0.00000e+000	0.00000	
4	1.602	PP	208.87331	0.00000e+000	0.00000	
4	2.873	BB	6.5143e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

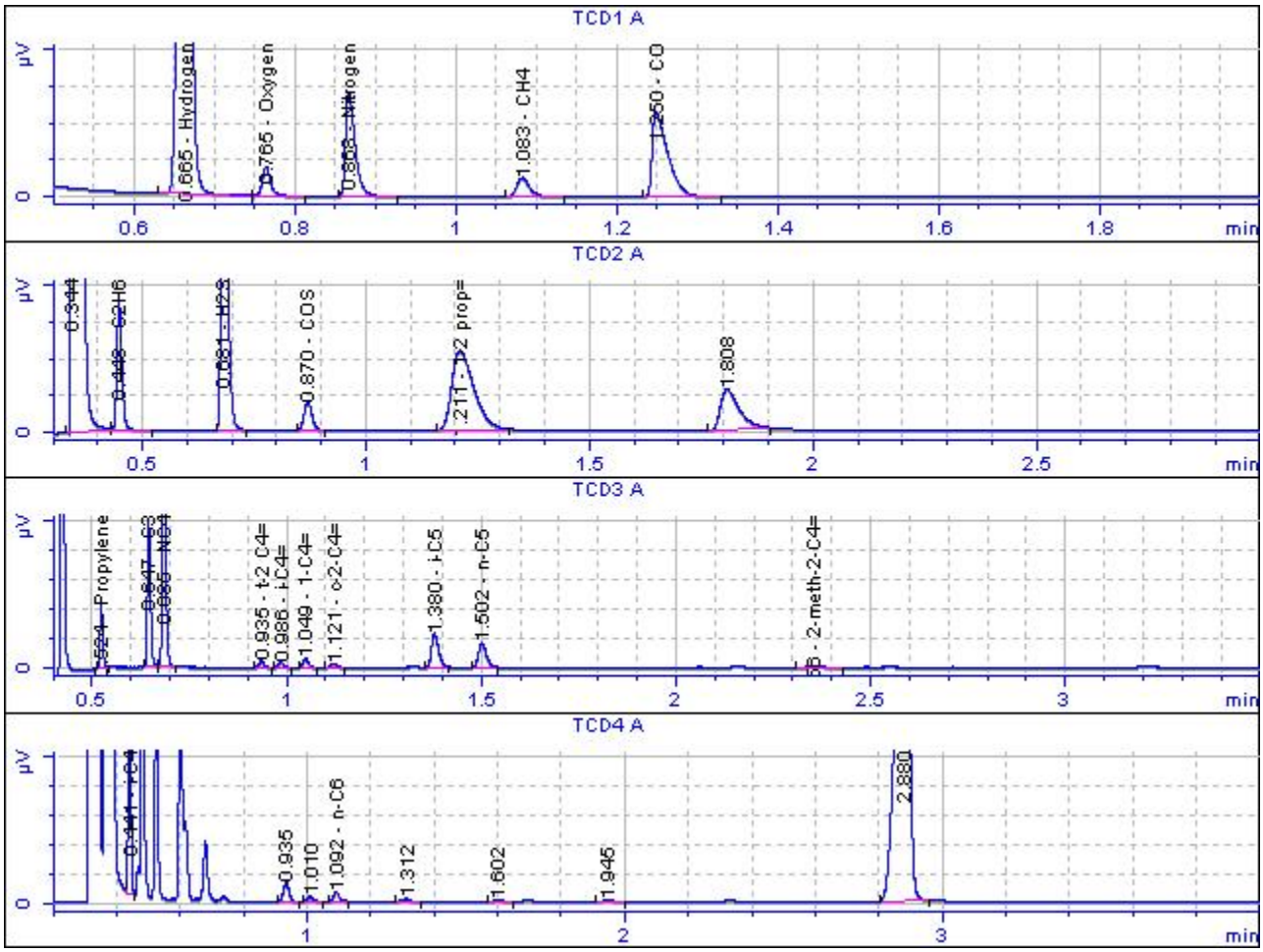
```
Total amount = 51.10969
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100COL, 60min
Sample note:	100 CO in lagre reactor at time =60
Submission time:	Thursday, May 28, 2009 12:34:47 PM
Operator:	Aziz
Injection date:	Thursday, May 28, 2009 12:35:33 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.665	BP	1.4723e+005	1.05208e-004	25.317831	Hydrogen
1	0.765	VP	2834.10714	1.06315e-003	4.924750	Oxygen
1	0.868	BB	1.1975e+004	1.25339e-003	24.531103	Nitrogen
1	1.083	BB	2996.79423	5.00940e-004	2.453676	CH4
1	1.250	BB	1.5859e+004	1.24655e-003	32.311032	CO
2	0.344	PB	5.4642e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	1.4228e+004	6.57906e-005	1.529996	C2H6
2	0.548		-	-	-	C2H2
2	0.681	BB	4.2076e+004	7.69512e-005	5.292052	H2S
2	0.870	BB	4949.45019	6.12584e-005	0.495561	COS
2	1.211	PB	3.7427e+004	1.85836e-005	1.136815	1-2 prop=
2	1.808	PB	1.6292e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	1109.80076	9.12409e-005	0.165504	Propylene
3	0.647	BV	2884.63713	1.02067e-004	0.481227	C3
3	0.685	VB	4456.41129	7.65293e-005	0.557427	NC4
3	0.935	PB	202.49653	8.11249e-005	0.026850	t-2 C4=
3	0.986	BB	155.40379	8.13163e-005	0.020654	i-C4=
3	1.049	BB	297.82477	8.30556e-005	0.040430	1-C4=
3	1.121	PP	127.72996	8.29864e-005	0.017325	c-2-C4=
3	1.380	PB	1471.66449	7.53631e-005	0.181277	i-C5
3	1.502	BB	1180.93465	7.49931e-005	0.144751	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.356	PP	116.66191	7.78266e-005	0.014840	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.652	BB	490.39314	0.00000e+000	0.000000	
4	0.441	BBA	8188.07904	2.45182e-005	0.328130	i-C4

4	0.935	BP	1605.95868	0.00000e+000	0.000000	
4	1.010	BP	520.98860	0.00000e+000	0.000000	
4	1.092	BB	863.08039	2.03938e-005	0.028769	n-C6
4	1.312	BP	332.57602	0.00000e+000	0.000000	
4	1.602	PP	209.11875	0.00000e+000	0.000000	
4	1.945	PB	247.24474	0.00000e+000	0.000000	
4	2.880	BB	8.7365e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.665	BP	1.4723e+005	1.05208e-004	15.49001	Hydrogen
1	0.765	VP	2834.10714	1.06315e-003	3.01307	Oxygen
1	0.868	BB	1.1975e+004	1.25339e-003	15.00867	Nitrogen
1	1.083	BB	2996.79423	5.00940e-004	1.50121	CH4
1	1.250	BB	1.5859e+004	1.24655e-003	19.76861	CO
2	0.344	PB	5.4642e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	1.4228e+004	6.57906e-005	0.93609	C2H6
2	0.548		-	-	-	C2H2
2	0.681	BB	4.2076e+004	7.69512e-005	3.23780	H2S
2	0.870	BB	4949.45019	6.12584e-005	0.30320	COS
2	1.211	PB	3.7427e+004	1.85836e-005	0.69553	1-2 prop=
2	1.808	PB	1.6292e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	1109.80076	9.12409e-005	0.10126	Propylene
3	0.647	BV	2884.63713	1.02067e-004	0.29443	C3
3	0.685	VB	4456.41129	7.65293e-005	0.34105	NC4
3	0.935	PB	202.49653	8.11249e-005	0.01643	t-2 C4=
3	0.986	BB	155.40379	8.13163e-005	0.01264	i-C4=
3	1.049	BB	297.82477	8.30556e-005	0.02474	1-C4=
3	1.121	PP	127.72996	8.29864e-005	0.01060	c-2-C4=
3	1.380	PB	1471.66449	7.53631e-005	0.11091	i-C5
3	1.502	BB	1180.93465	7.49931e-005	0.08856	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.356	PP	116.66191	7.78266e-005	0.00908	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.652	BB	490.39314	0.00000e+000	0.00000	
4	0.441	BBA	8188.07904	2.45182e-005	0.20076	i-C4

4	0.935	BP	1605.95868	0.00000e+000	0.00000	
4	1.010	BP	520.98860	0.00000e+000	0.00000	
4	1.092	BB	863.08039	2.03938e-005	0.01760	n-C6
4	1.312	BP	332.57602	0.00000e+000	0.00000	
4	1.602	PP	209.11875	0.00000e+000	0.00000	
4	1.945	PB	247.24474	0.00000e+000	0.00000	
4	2.880	BB	8.7365e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

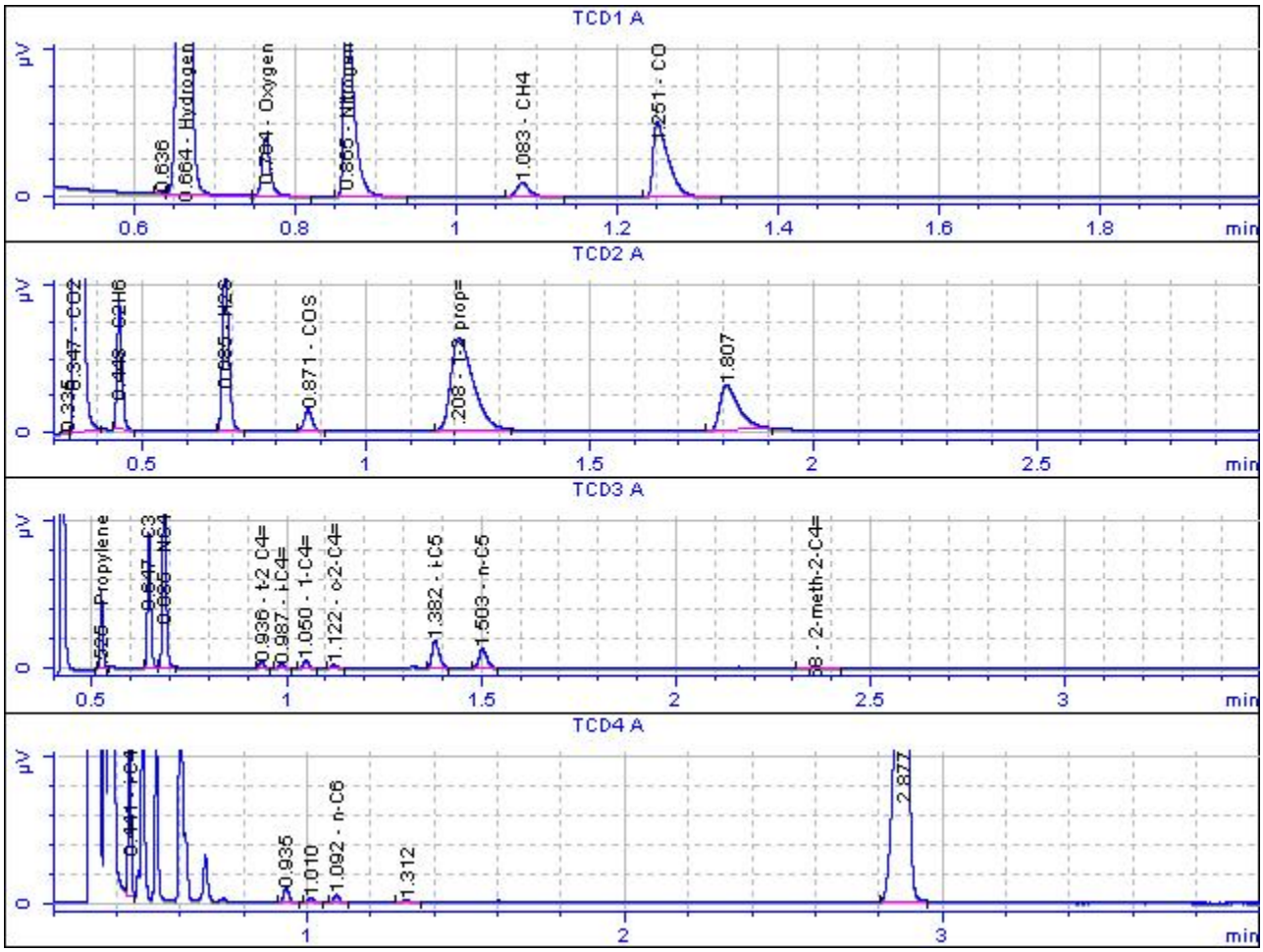
```
Total amount = 61.18223
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100COL, 30min
Sample note:	100 CO in lagre reactor at time =30
Submission time:	Thursday, May 28, 2009 12:07:01 PM
Operator:	Aziz
Injection date:	Thursday, May 28, 2009 12:07:48 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.636	BV	83.57774	0.00000e+000	0.000000	
1	0.664	VP	1.0348e+005	1.05208e-004	11.044824	Hydrogen
1	0.764	VB	5776.31364	1.06315e-003	6.230382	Oxygen
1	0.865	BB	2.4401e+004	1.25339e-003	31.028330	Nitrogen
1	1.083	BB	2255.41973	5.00940e-004	1.146261	CH4
1	1.251	BB	1.3522e+004	1.24655e-003	17.101412	CO
2	0.335	PP	78.14403	0.00000e+000	0.000000	
2	0.347	VB	3.8991e+005	7.24041e-005	28.641405	CO2
2	0.409		-	-	-	C2H4
2	0.448	PB	1.3330e+004	6.57906e-005	0.889769	C2H6
2	0.548		-	-	-	C2H2
2	0.685	BB	2.2190e+004	7.69512e-005	1.732374	H2S
2	0.871	BB	3608.28538	6.12584e-005	0.224252	COS
2	1.208	PB	4.4074e+004	1.85836e-005	0.830970	1-2 prop=
2	1.807	PB	1.8134e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	1347.07035	9.12409e-005	0.124695	Propylene
3	0.647	BV	2673.48073	1.02067e-004	0.276842	C3
3	0.685	VB	3850.06259	7.65293e-005	0.298928	NC4
3	0.936	BB	171.22140	8.11249e-005	0.014092	t-2 C4=
3	0.987	BB	134.47456	8.13163e-005	0.011094	i-C4=
3	1.050	PB	263.66569	8.30556e-005	0.022217	1-C4=
3	1.122	BP	105.36562	8.29864e-005	0.008871	c-2-C4=
3	1.382	BB	1183.18557	7.53631e-005	0.090465	i-C5
3	1.503	BB	924.52550	7.49931e-005	0.070341	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.358	PP	86.03873	7.78266e-005	0.006793	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.656	BB	408.54225	0.00000e+000	0.000000	

4	0.441	BBA	7708.12326	2.45182e-005	0.191738	i-C4
4	0.935	BP	1260.50142	0.00000e+000	0.000000	
4	1.010	BP	411.93178	0.00000e+000	0.000000	
4	1.092	BB	673.86593	2.03938e-005	0.013943	n-C6
4	1.312	BP	272.45746	0.00000e+000	0.000000	
4	2.877	BB	7.4852e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.636	BV	83.57774	0.00000e+000	0.00000	
1	0.664	VP	1.0348e+005	1.05208e-004	10.88649	Hydrogen
1	0.764	VB	5776.31364	1.06315e-003	6.14107	Oxygen
1	0.865	BB	2.4401e+004	1.25339e-003	30.58353	Nitrogen
1	1.083	BB	2255.41973	5.00940e-004	1.12983	CH4
1	1.251	BB	1.3522e+004	1.24655e-003	16.85626	CO
2	0.335	PP	78.14403	0.00000e+000	0.00000	
2	0.347	VB	3.8991e+005	7.24041e-005	28.23083	CO2
2	0.409		-	-	-	C2H4
2	0.448	PB	1.3330e+004	6.57906e-005	0.87701	C2H6
2	0.548		-	-	-	C2H2
2	0.685	BB	2.2190e+004	7.69512e-005	1.70754	H2S
2	0.871	BB	3608.28538	6.12584e-005	0.22104	COS
2	1.208	PB	4.4074e+004	1.85836e-005	0.81906	1-2 prop=
2	1.807	PB	1.8134e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.525	BB	1347.07035	9.12409e-005	0.12291	Propylene
3	0.647	BV	2673.48073	1.02067e-004	0.27287	C3
3	0.685	VB	3850.06259	7.65293e-005	0.29464	NC4
3	0.936	BB	171.22140	8.11249e-005	0.01389	t-2 C4=
3	0.987	BB	134.47456	8.13163e-005	0.01093	i-C4=
3	1.050	PB	263.66569	8.30556e-005	0.02190	1-C4=
3	1.122	BP	105.36562	8.29864e-005	0.00874	c-2-C4=
3	1.382	BB	1183.18557	7.53631e-005	0.08917	i-C5
3	1.503	BB	924.52550	7.49931e-005	0.06933	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.358	PP	86.03873	7.78266e-005	0.00670	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.656	BB	408.54225	0.00000e+000	0.00000	

4	0.441	BBA	7708.12326	2.45182e-005	0.18899	i-C4
4	0.935	BP	1260.50142	0.00000e+000	0.00000	
4	1.010	BP	411.93178	0.00000e+000	0.00000	
4	1.092	BB	673.86593	2.03938e-005	0.01374	n-C6
4	1.312	BP	272.45746	0.00000e+000	0.00000	
4	2.877	BB	7.4852e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

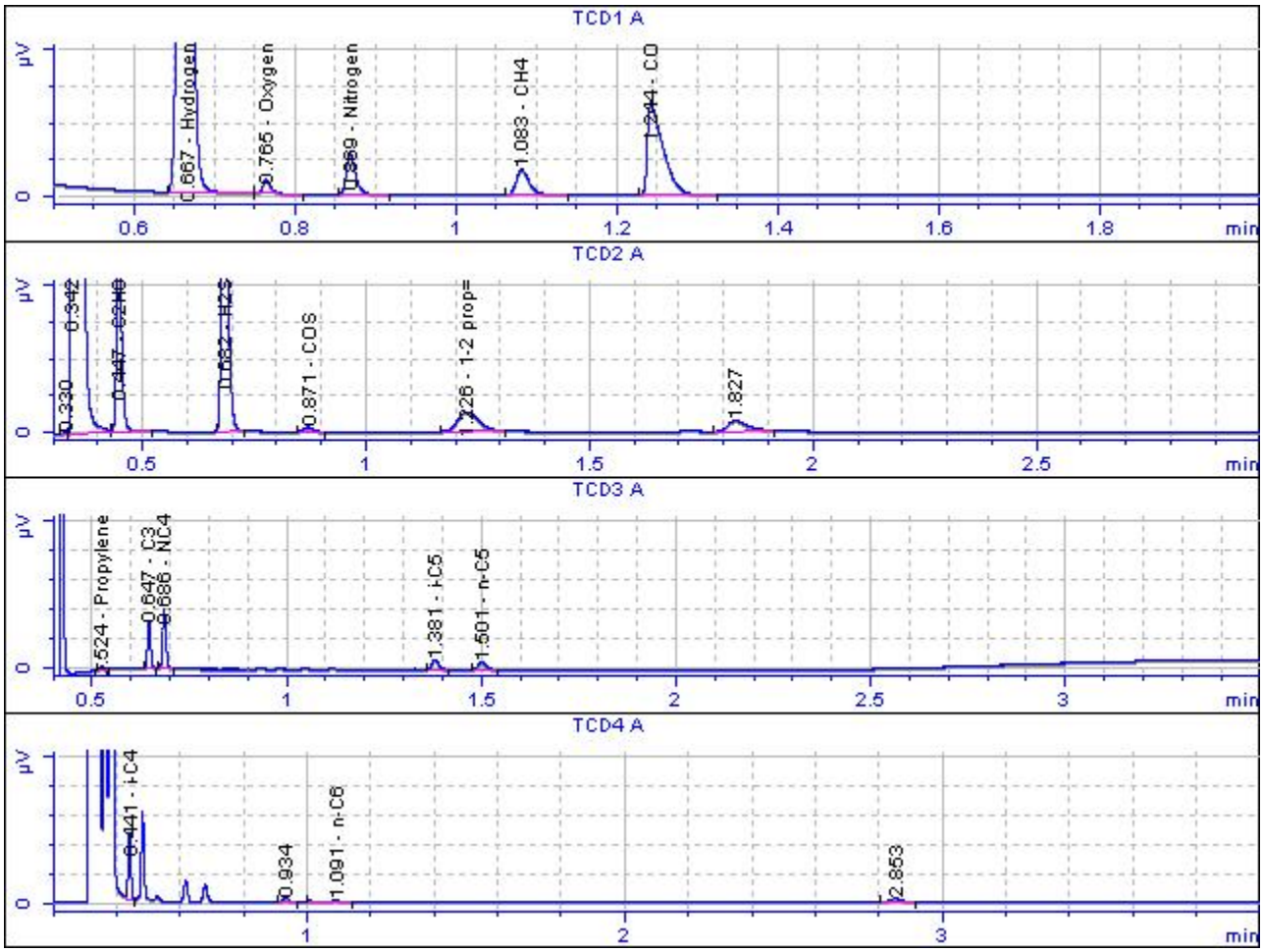
```
Total amount = 98.56648
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO2000Mo-OVNT-3
Sample note:	2000 ppm Mo to LGO mass under pure CO Final P=525 psi at 24 C
Submission time:	Saturday, May 30, 2009 2:49:16 PM
Operator:	Aziz
Injection date:	Saturday, May 30, 2009 3:00:17 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.667	BP	2.0708e+005	1.05208e-004	38.083345	Hydrogen
1	0.765	VP	1352.49392	1.06315e-003	2.513443	Oxygen
1	0.869	BB	4561.69274	1.25339e-003	9.994277	Nitrogen
1	1.083	BB	3948.43902	5.00940e-004	3.457414	CH4
1	1.244	BB	1.7175e+004	1.24655e-003	37.423233	CO
2	0.330	PP	111.45512	0.00000e+000	0.000000	
2	0.342	VB	6.4498e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.447	BB	2.1310e+004	6.57906e-005	2.450707	C2H6
2	0.548		-	-	-	C2H2
2	0.682	BB	3.8106e+004	7.69512e-005	5.125658	H2S
2	0.871	PB	768.17721	6.12584e-005	0.082256	COS
2	1.226	PB	8689.13119	1.85836e-005	0.282258	1-2 prop=
2	1.827	PB	4382.54284	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	102.42349	9.12409e-005	0.016335	Propylene
3	0.647	BB	940.81674	1.02067e-004	0.167853	C3
3	0.686	BB	1307.52947	7.65293e-005	0.174912	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.381	BB	408.76544	7.53631e-005	0.053848	i-C5
3	1.501	BB	330.53112	7.49931e-005	0.043329	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BBA	2772.27376	2.45182e-005	0.118814	i-C4

4	0.934	BP	420.88540	0.00000e+000	0.000000	
4	1.091	BP	345.54320	2.03938e-005	0.012318	n-C6
4	2.853	BP	537.58625	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.667	BP	2.0708e+005	1.05208e-004	21.78686	Hydrogen
1	0.765	VP	1352.49392	1.06315e-003	1.43790	Oxygen
1	0.869	BB	4561.69274	1.25339e-003	5.71756	Nitrogen
1	1.083	BB	3948.43902	5.00940e-004	1.97793	CH4
1	1.244	BB	1.7175e+004	1.24655e-003	21.40922	CO
2	0.330	PP	111.45512	0.00000e+000	0.00000	
2	0.342	VB	6.4498e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.447	BB	2.1310e+004	6.57906e-005	1.40201	C2H6
2	0.548		-	-	-	C2H2
2	0.682	BB	3.8106e+004	7.69512e-005	2.93230	H2S
2	0.871	PB	768.17721	6.12584e-005	0.04706	COS
2	1.226	PB	8689.13119	1.85836e-005	0.16148	1-2 prop=
2	1.827	PB	4382.54284	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.524	BB	102.42349	9.12409e-005	0.00935	Propylene
3	0.647	BB	940.81674	1.02067e-004	0.09603	C3
3	0.686	BB	1307.52947	7.65293e-005	0.10006	NC4
3	0.939		-	-	-	t-2 C4=
3	0.990		-	-	-	i-C4=
3	1.052		-	-	-	1-C4=
3	1.126		-	-	-	c-2-C4=
3	1.381	BB	408.76544	7.53631e-005	0.03081	i-C5
3	1.501	BB	330.53112	7.49931e-005	0.02479	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.406		-	-	-	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
4	0.441	BBA	2772.27376	2.45182e-005	0.06797	i-C4

4	0.934	BP	420.88540	0.00000e+000	0.00000	
4	1.091	BP	345.54320	2.03938e-005	0.00705	n-C6
4	2.853	BP	537.58625	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

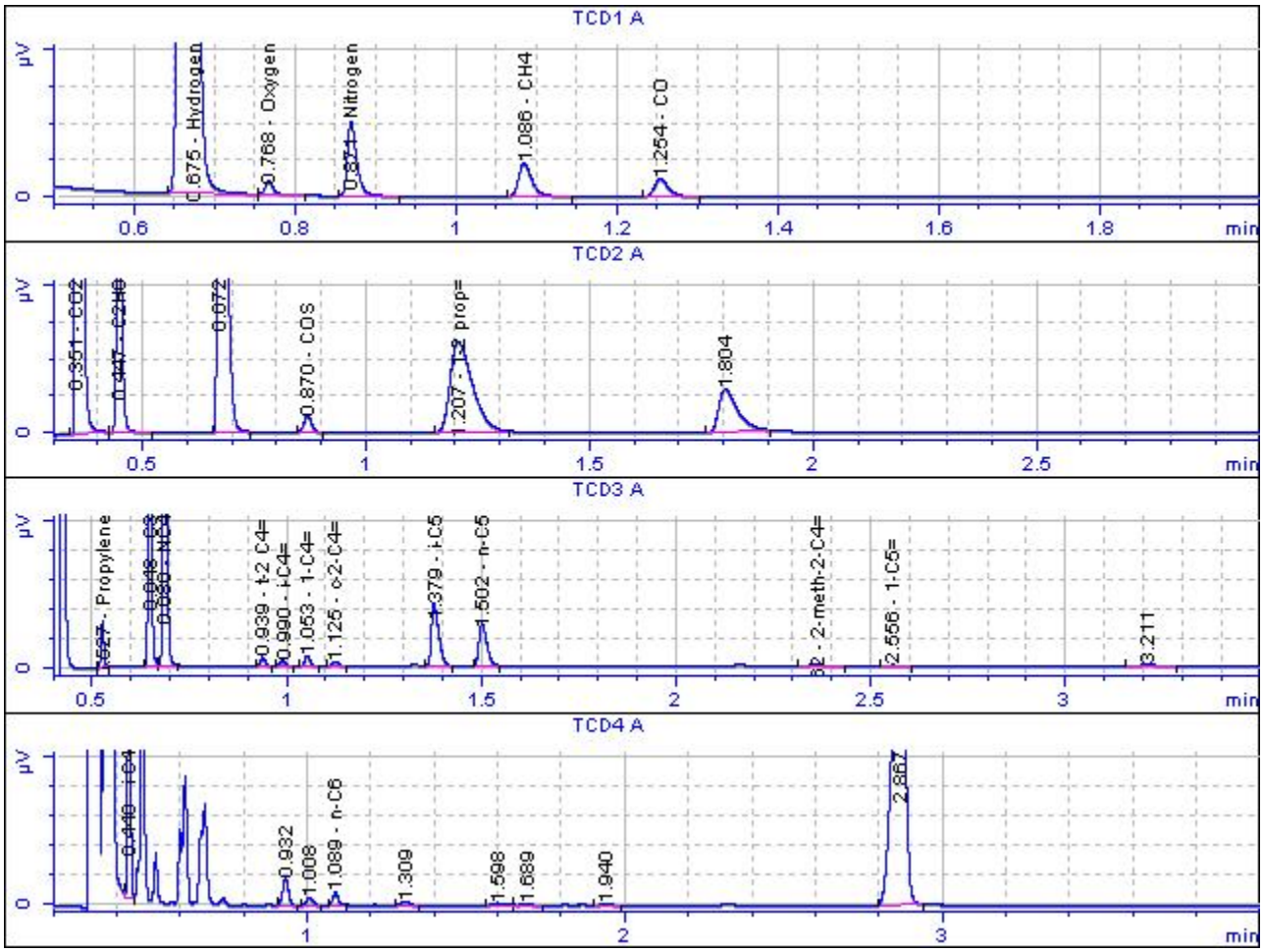
```
Total amount = 57.20836
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100HL, 90min
Sample note:	100 H in lagre reactor at time =90
Submission time:	Tuesday, June 02, 2009 2:04:34 PM
Operator:	Aziz
Injection date:	Tuesday, June 02, 2009 2:05:26 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.675	BV	5.1175e+005	1.05208e-004	55.557884	Hydrogen
1	0.768	VP	1392.40077	1.06315e-003	1.527556	Oxygen
1	0.871	BB	8199.76080	1.25339e-003	10.605371	Nitrogen
1	1.086	BB	5207.65409	5.00940e-004	2.691953	CH4
1	1.254	BB	2859.73244	1.24655e-003	3.678528	CO
2	0.351	PB	2.7846e+005	7.24041e-005	20.804896	CO2
2	0.409		-	-	-	C2H4
2	0.447	BB	2.9145e+004	6.57906e-005	1.978636	C2H6
2	0.548		-	-	-	C2H2
2	0.672	PB	1.0891e+005	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.870	BB	2834.06808	6.12584e-005	0.179149	COS
2	1.207	PB	4.3069e+004	1.85836e-005	0.825914	1-2 prop=
2	1.804	PB	1.7006e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	790.73425	9.12409e-005	0.074449	Propylene
3	0.648	BV	5391.56232	1.02067e-004	0.567856	C3
3	0.686	VB	8418.45424	7.65293e-005	0.664814	NC4
3	0.939	BB	251.52027	8.11249e-005	0.021056	t-2 C4=
3	0.990	BP	181.75335	8.13163e-005	0.015251	i-C4=
3	1.053	BB	336.36879	8.30556e-005	0.028829	1-C4=
3	1.125	BP	158.27518	8.29864e-005	0.013554	c-2-C4=
3	1.379	PB	2748.46809	7.53631e-005	0.213742	i-C5
3	1.502	BB	2083.73455	7.49931e-005	0.161251	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.362	PP	140.41098	7.78266e-005	0.011276	2-meth-2-C4=
3	2.556	BP	64.73993	7.76562e-005	0.005188	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.211	PB	151.71468	0.00000e+000	0.000000	
3	3.650	BB	899.88934	0.00000e+000	0.000000	

4	0.440	BBA	1.3826e+004	2.45182e-005	0.349801	i-C4
4	0.932	BP	2264.97963	0.00000e+000	0.000000	
4	1.008	BP	703.47604	0.00000e+000	0.000000	
4	1.089	BB	1095.09656	2.03938e-005	0.023046	n-C6
4	1.309	BP	420.34454	0.00000e+000	0.000000	
4	1.598	PB	355.61332	0.00000e+000	0.000000	
4	1.689	BP	286.37022	0.00000e+000	0.000000	
4	1.940	PB	256.45579	0.00000e+000	0.000000	
4	2.867	BB	6.7688e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.675	BV	5.1175e+005	1.05208e-004	53.84011	Hydrogen
1	0.768	VP	1392.40077	1.06315e-003	1.48033	Oxygen
1	0.871	BB	8199.76080	1.25339e-003	10.27747	Nitrogen
1	1.086	BB	5207.65409	5.00940e-004	2.60872	CH4
1	1.254	BB	2859.73244	1.24655e-003	3.56479	CO
2	0.351	PB	2.7846e+005	7.24041e-005	20.16164	CO2
2	0.409		-	-	-	C2H4
2	0.447	BB	2.9145e+004	6.57906e-005	1.91746	C2H6
2	0.548		-	-	-	C2H2
2	0.672	PB	1.0891e+005	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.870	BB	2834.06808	6.12584e-005	0.17361	COS
2	1.207	PB	4.3069e+004	1.85836e-005	0.80038	1-2 prop=
2	1.804	PB	1.7006e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	790.73425	9.12409e-005	0.07215	Propylene
3	0.648	BV	5391.56232	1.02067e-004	0.55030	C3
3	0.686	VB	8418.45424	7.65293e-005	0.64426	NC4
3	0.939	BB	251.52027	8.11249e-005	0.02040	t-2 C4=
3	0.990	BP	181.75335	8.13163e-005	0.01478	i-C4=
3	1.053	BB	336.36879	8.30556e-005	0.02794	1-C4=
3	1.125	BP	158.27518	8.29864e-005	0.01313	c-2-C4=
3	1.379	PB	2748.46809	7.53631e-005	0.20713	i-C5
3	1.502	BB	2083.73455	7.49931e-005	0.15627	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.362	PP	140.41098	7.78266e-005	0.01093	2-meth-2-C4=
3	2.556	BP	64.73993	7.76562e-005	0.00503	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.211	PB	151.71468	0.00000e+000	0.00000	
3	3.650	BB	899.88934	0.00000e+000	0.00000	

4	0.440	BBA	1.3826e+004	2.45182e-005	0.33899	i-C4
4	0.932	BP	2264.97963	0.00000e+000	0.00000	
4	1.008	BP	703.47604	0.00000e+000	0.00000	
4	1.089	BB	1095.09656	2.03938e-005	0.02233	n-C6
4	1.309	BP	420.34454	0.00000e+000	0.00000	
4	1.598	PB	355.61332	0.00000e+000	0.00000	
4	1.689	BP	286.37022	0.00000e+000	0.00000	
4	1.940	PB	256.45579	0.00000e+000	0.00000	
4	2.867	BB	6.7688e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

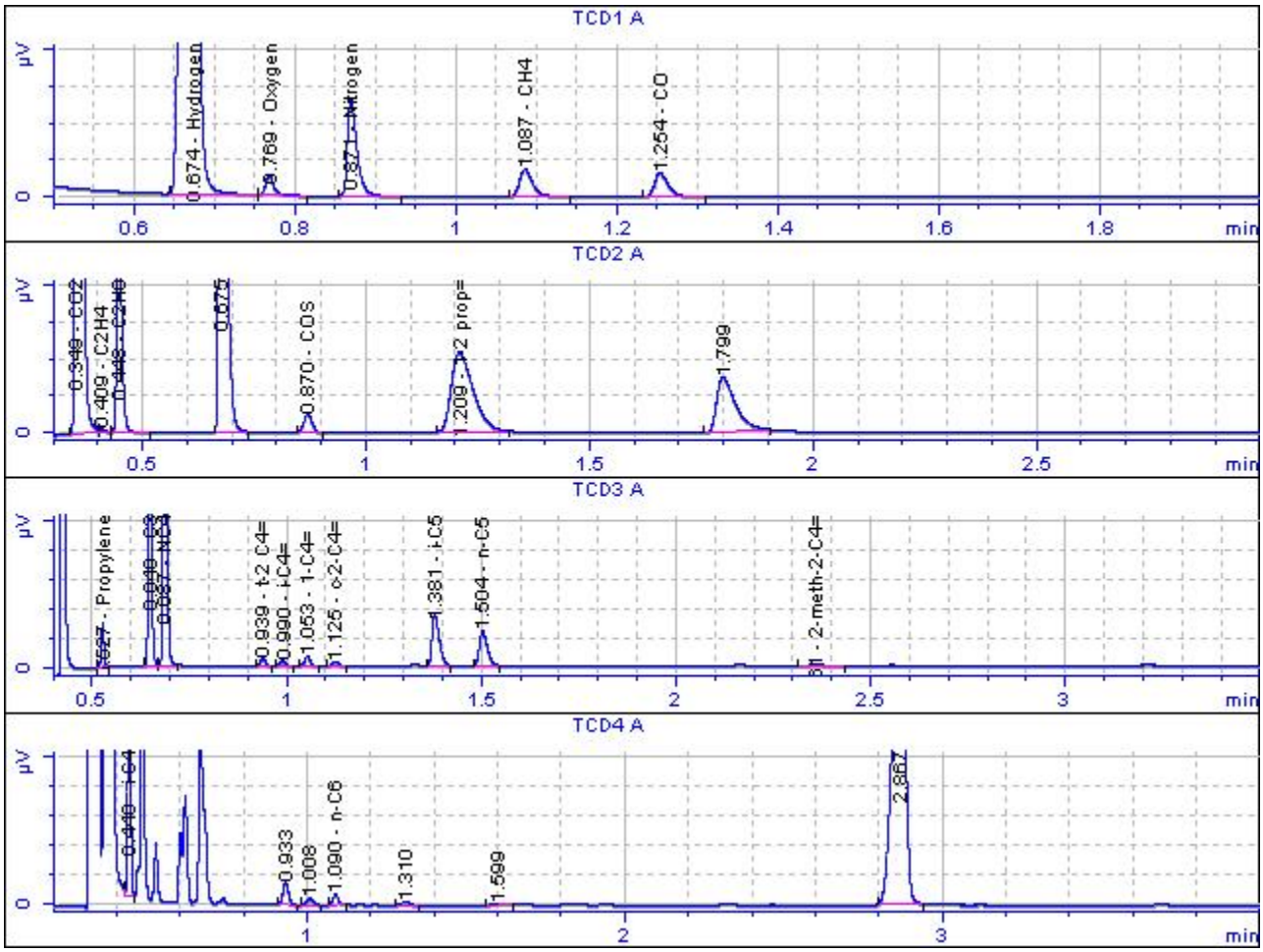
```
Total amount = 96.90813
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100HL, 60min
Sample note:	100 H in lagre reactor at time =60
Submission time:	Tuesday, June 02, 2009 1:36:27 PM
Operator:	Aziz
Injection date:	Tuesday, June 02, 2009 1:37:23 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.674	BV	4.1577e+005	1.05208e-004	45.691604	Hydrogen
1	0.769	VB	1941.41198	1.06315e-003	2.155970	Oxygen
1	0.871	BB	1.0860e+004	1.25339e-003	14.218653	Nitrogen
1	1.087	BB	4229.57144	5.00940e-004	2.213164	CH4
1	1.254	BB	3857.15339	1.24655e-003	5.022356	CO
2	0.349	PV	3.4792e+005	7.24041e-005	26.312975	CO2
2	0.409	VV	564.14456	7.03854e-005	0.041477	C2H4
2	0.448	VB	2.3130e+004	6.57906e-005	1.589547	C2H6
2	0.548		-	-	-	C2H2
2	0.675	BB	8.2862e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.870	BB	3129.85514	6.12584e-005	0.200273	COS
2	1.209	PB	3.7171e+004	1.85836e-005	0.721547	1-2 prop=
2	1.799	PB	2.1839e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	760.32191	9.12409e-005	0.072463	Propylene
3	0.649	BV	4499.35157	1.02067e-004	0.479696	C3
3	0.687	VB	6981.83645	7.65293e-005	0.558122	NC4
3	0.939	BB	227.32693	8.11249e-005	0.019264	t-2 C4=
3	0.990	BP	164.96423	8.13163e-005	0.014012	i-C4=
3	1.053	BB	311.63677	8.30556e-005	0.027036	1-C4=
3	1.125	BP	144.76616	8.29864e-005	0.012549	c-2-C4=
3	1.381	BB	2229.34600	7.53631e-005	0.175496	i-C5
3	1.504	BB	1689.23320	7.49931e-005	0.132325	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.361	PP	129.62657	7.78266e-005	0.010538	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.651	BB	717.54905	0.00000e+000	0.000000	
4	0.440	BBA	1.2163e+004	2.45182e-005	0.311503	i-C4

4	0.933	BP	1906.06730	0.00000e+000	0.000000	
4	1.008	BP	592.31351	0.00000e+000	0.000000	
4	1.090	BB	912.12241	2.03938e-005	0.019430	n-C6
4	1.310	BP	364.23457	0.00000e+000	0.000000	
4	1.599	PP	212.47601	0.00000e+000	0.000000	
4	2.867	BB	6.6968e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.674	BV	4.1577e+005	1.05208e-004	43.74260	Hydrogen
1	0.769	VB	1941.41198	1.06315e-003	2.06401	Oxygen
1	0.871	BB	1.0860e+004	1.25339e-003	13.61215	Nitrogen
1	1.087	BB	4229.57144	5.00940e-004	2.11876	CH4
1	1.254	BB	3857.15339	1.24655e-003	4.80813	CO
2	0.349	PV	3.4792e+005	7.24041e-005	25.19058	CO2
2	0.409	VV	564.14456	7.03854e-005	0.03971	C2H4
2	0.448	VB	2.3130e+004	6.57906e-005	1.52174	C2H6
2	0.548		-	-	-	C2H2
2	0.675	BB	8.2862e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.870	BB	3129.85514	6.12584e-005	0.19173	COS
2	1.209	PB	3.7171e+004	1.85836e-005	0.69077	1-2 prop=
2	1.799	PB	2.1839e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	760.32191	9.12409e-005	0.06937	Propylene
3	0.649	BV	4499.35157	1.02067e-004	0.45923	C3
3	0.687	VB	6981.83645	7.65293e-005	0.53432	NC4
3	0.939	BB	227.32693	8.11249e-005	0.01844	t-2 C4=
3	0.990	BP	164.96423	8.13163e-005	0.01341	i-C4=
3	1.053	BB	311.63677	8.30556e-005	0.02588	1-C4=
3	1.125	BP	144.76616	8.29864e-005	0.01201	c-2-C4=
3	1.381	BB	2229.34600	7.53631e-005	0.16801	i-C5
3	1.504	BB	1689.23320	7.49931e-005	0.12668	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.361	PP	129.62657	7.78266e-005	0.01009	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.651	BB	717.54905	0.00000e+000	0.00000	
4	0.440	BBA	1.2163e+004	2.45182e-005	0.29822	i-C4

4	0.933	BP	1906.06730	0.00000e+000	0.00000	
4	1.008	BP	592.31351	0.00000e+000	0.00000	
4	1.090	BB	912.12241	2.03938e-005	0.01860	n-C6
4	1.310	BP	364.23457	0.00000e+000	0.00000	
4	1.599	PP	212.47601	0.00000e+000	0.00000	
4	2.867	BB	6.6968e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

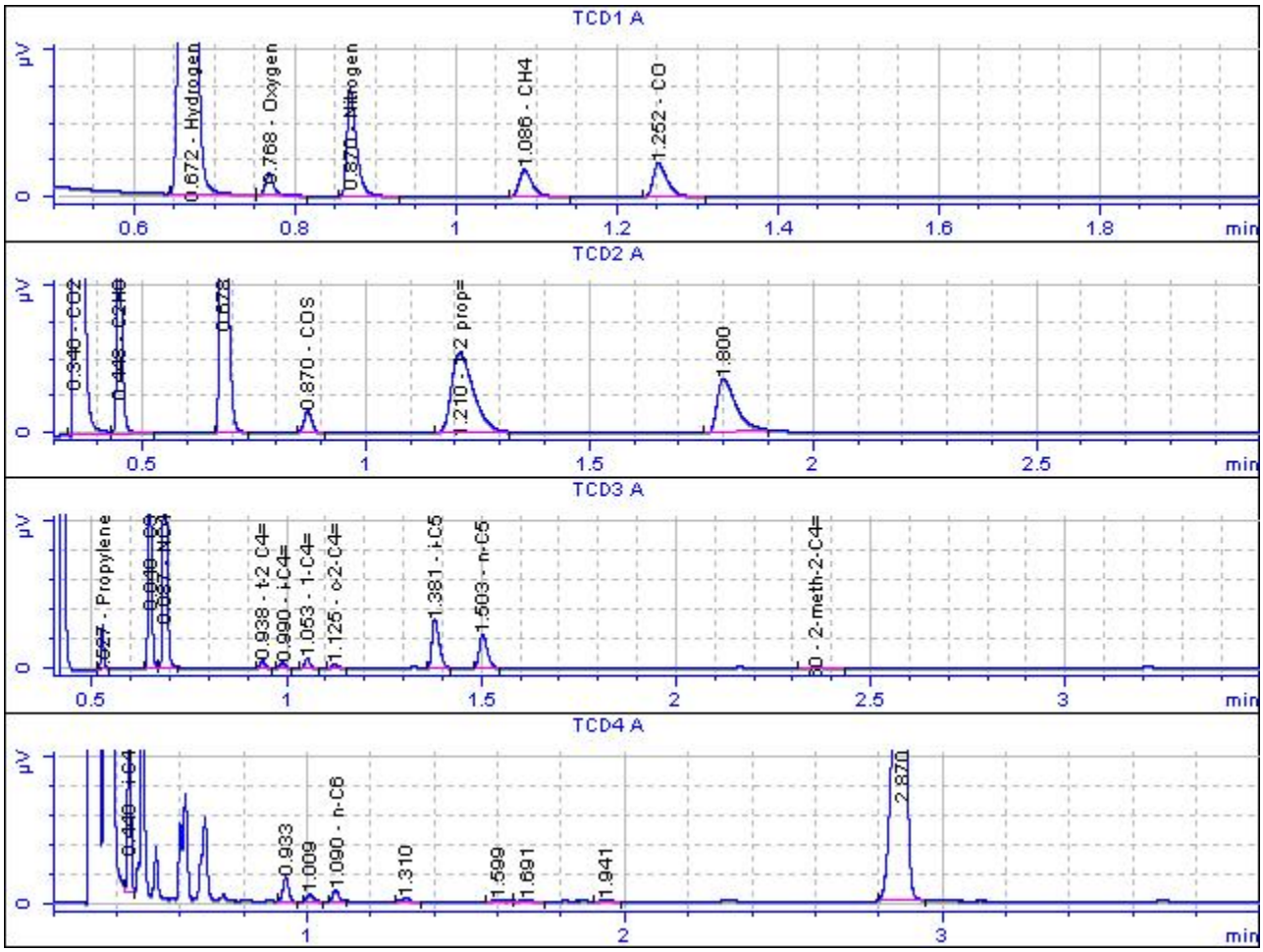
```
Total amount = 95.73445
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100HL, 30min
Sample note:	100 H in lagre reactor at time =30
Submission time:	Tuesday, June 02, 2009 1:06:37 PM
Operator:	Aziz
Injection date:	Tuesday, June 02, 2009 1:07:55 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.672	BV	3.0442e+005	1.05208e-004	33.129554	Hydrogen
1	0.768	VP	2107.16717	1.06315e-003	2.317323	Oxygen
1	0.870	BB	1.2079e+004	1.25339e-003	15.661170	Nitrogen
1	1.086	BB	4184.54213	5.00940e-004	2.168342	CH4
1	1.252	BB	5528.23745	1.24655e-003	7.128364	CO
2	0.346	PB	4.7240e+005	7.24041e-005	35.380486	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	2.2095e+004	6.57906e-005	1.503637	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	6.9194e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.870	BB	3766.08331	6.12584e-005	0.238644	COS
2	1.210	PB	3.7503e+004	1.85836e-005	0.720920	1-2 prop=
2	1.800	PB	2.1514e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	762.08410	9.12409e-005	0.071926	Propylene
3	0.649	BV	4295.76228	1.02067e-004	0.453543	C3
3	0.687	VB	6633.74603	7.65293e-005	0.525147	NC4
3	0.938	BB	223.02064	8.11249e-005	0.018715	t-2 C4=
3	0.990	BB	158.64935	8.13163e-005	0.013345	i-C4=
3	1.053	BB	307.72620	8.30556e-005	0.026438	1-C4=
3	1.125	PP	140.57544	8.29864e-005	0.012067	c-2-C4=
3	1.381	BB	2153.64155	7.53631e-005	0.167891	i-C5
3	1.503	BB	1657.44434	7.49931e-005	0.128574	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.360	PP	130.82138	7.78266e-005	0.010532	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.651	BB	672.72703	0.00000e+000	0.000000	
4	0.440	BBA	1.1905e+004	2.45182e-005	0.301942	i-C4

4	0.933	BP	2052.70915	0.00000e+000	0.000000	
4	1.009	BP	653.34948	0.00000e+000	0.000000	
4	1.090	BB	1016.31459	2.03938e-005	0.021440	n-C6
4	1.310	BP	402.29907	0.00000e+000	0.000000	
4	1.599	PB	360.24115	0.00000e+000	0.000000	
4	1.691	BP	281.02195	0.00000e+000	0.000000	
4	1.941	PB	262.09279	0.00000e+000	0.000000	
4	2.870	BB	7.2331e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

```
Total norm percent = 100.00000
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.672	BV	3.0442e+005	1.05208e-004	32.02737	Hydrogen
1	0.768	VP	2107.16717	1.06315e-003	2.24023	Oxygen
1	0.870	BB	1.2079e+004	1.25339e-003	15.14014	Nitrogen
1	1.086	BB	4184.54213	5.00940e-004	2.09620	CH4
1	1.252	BB	5528.23745	1.24655e-003	6.89121	CO
2	0.346	PB	4.7240e+005	7.24041e-005	34.20341	CO2
2	0.409		-	-	-	C2H4
2	0.448	BB	2.2095e+004	6.57906e-005	1.45361	C2H6
2	0.548		-	-	-	C2H2
2	0.678	BB	6.9194e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.870	BB	3766.08331	6.12584e-005	0.23070	COS
2	1.210	PB	3.7503e+004	1.85836e-005	0.69694	1-2 prop=
2	1.800	PB	2.1514e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	762.08410	9.12409e-005	0.06953	Propylene
3	0.649	BV	4295.76228	1.02067e-004	0.43845	C3
3	0.687	VB	6633.74603	7.65293e-005	0.50768	NC4
3	0.938	BB	223.02064	8.11249e-005	0.01809	t-2 C4=
3	0.990	BB	158.64935	8.13163e-005	0.01290	i-C4=
3	1.053	BB	307.72620	8.30556e-005	0.02556	1-C4=
3	1.125	PP	140.57544	8.29864e-005	0.01167	c-2-C4=
3	1.381	BB	2153.64155	7.53631e-005	0.16231	i-C5
3	1.503	BB	1657.44434	7.49931e-005	0.12430	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.360	PP	130.82138	7.78266e-005	0.01018	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.651	BB	672.72703	0.00000e+000	0.00000	
4	0.440	BBA	1.1905e+004	2.45182e-005	0.29190	i-C4

4	0.933	BP	2052.70915	0.00000e+000	0.00000	
4	1.009	BP	653.34948	0.00000e+000	0.00000	
4	1.090	BB	1016.31459	2.03938e-005	0.02073	n-C6
4	1.310	BP	402.29907	0.00000e+000	0.00000	
4	1.599	PB	360.24115	0.00000e+000	0.00000	
4	1.691	BP	281.02195	0.00000e+000	0.00000	
4	1.941	PB	262.09279	0.00000e+000	0.00000	
4	2.870	BB	7.2331e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

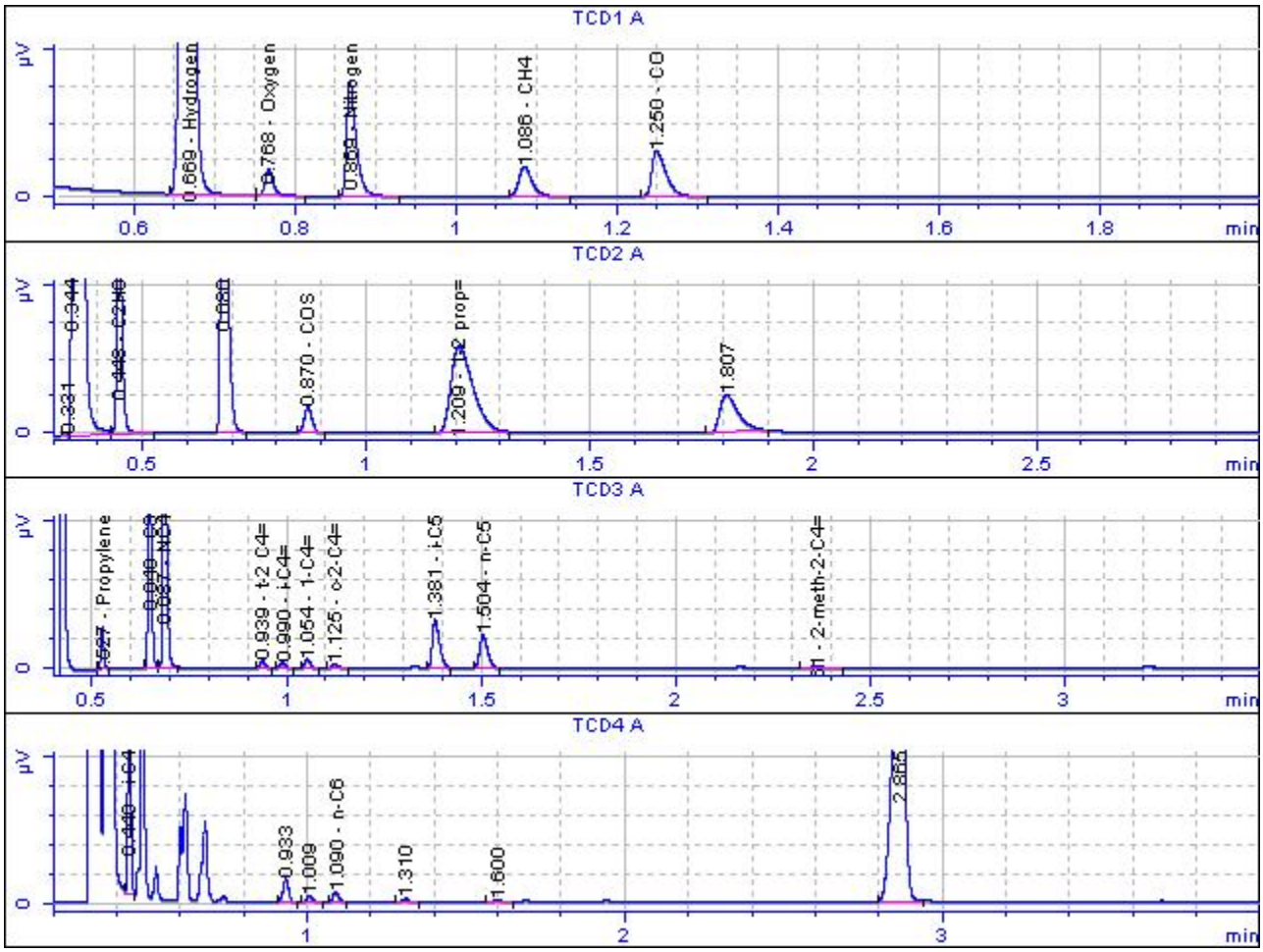
```
Total amount = 96.67310
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100HL, 0min
Sample note:	100 H in lagre reactor at time =0
Submission time:	Tuesday, June 02, 2009 1:01:06 PM
Operator:	Aziz
Injection date:	Tuesday, June 02, 2009 1:02:51 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.669	BP	1.7728e+005	1.05208e-004	34.480836	Hydrogen
1	0.768	VP	2487.31603	1.06315e-003	4.888577	Oxygen
1	0.869	BB	1.3068e+004	1.25339e-003	30.280127	Nitrogen
1	1.086	BB	4745.98333	5.00940e-004	4.395113	CH4
1	1.250	BB	7791.00975	1.24655e-003	17.953987	CO
2	0.331	PP	97.58698	0.00000e+000	0.000000	
2	0.344	VV	6.1271e+005	0.00000e+000	0.000000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	VB	2.4075e+004	6.57906e-005	2.928057	C2H6
2	0.548		-	-	-	C2H2
2	0.680	BB	5.4071e+004	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.870	BB	4460.54736	6.12584e-005	0.505140	COS
2	1.209	PB	4.0756e+004	1.85836e-005	1.400155	1-2 prop=
2	1.807	PB	1.4963e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	750.80222	9.12409e-005	0.126641	Propylene
3	0.649	BV	4475.38858	1.02067e-004	0.844449	C3
3	0.687	VB	6697.84171	7.65293e-005	0.947591	NC4
3	0.939	BB	206.17771	8.11249e-005	0.030921	t-2 C4=
3	0.990	BB	145.23926	8.13163e-005	0.021833	i-C4=
3	1.054	BB	279.30612	8.30556e-005	0.042885	1-C4=
3	1.125	PP	128.38203	8.29864e-005	0.019696	c-2-C4=
3	1.381	BB	2108.69080	7.53631e-005	0.293785	i-C5
3	1.504	BB	1584.44403	7.49931e-005	0.219663	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.361	PP	105.00160	7.78266e-005	0.015107	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.654	BB	707.08857	0.00000e+000	0.000000	
4	0.440	BBA	1.2575e+004	2.45182e-005	0.569991	i-C4
4	0.933	BP	1946.79382	0.00000e+000	0.000000	
4	1.009	BP	609.00943	0.00000e+000	0.000000	
4	1.090	BB	940.18802	2.03938e-005	0.035446	n-C6
4	1.310	BP	382.98583	0.00000e+000	0.000000	
4	1.600	PP	213.80978	0.00000e+000	0.000000	
4	2.865	BB	5.4316e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.669	BP	1.7728e+005	1.05208e-004	18.65174	Hydrogen
1	0.768	VP	2487.31603	1.06315e-003	2.64438	Oxygen
1	0.869	BB	1.3068e+004	1.25339e-003	16.37945	Nitrogen
1	1.086	BB	4745.98333	5.00940e-004	2.37745	CH4
1	1.250	BB	7791.00975	1.24655e-003	9.71186	CO
2	0.331	PP	97.58698	0.00000e+000	0.00000	
2	0.344	VV	6.1271e+005	0.00000e+000	0.00000	
2	0.355		-	-	-	CO2
2	0.409		-	-	-	C2H4
2	0.448	VB	2.4075e+004	6.57906e-005	1.58388	C2H6
2	0.548		-	-	-	C2H2
2	0.680	BB	5.4071e+004	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.870	BB	4460.54736	6.12584e-005	0.27325	COS
2	1.209	PB	4.0756e+004	1.85836e-005	0.75739	1-2 prop=
2	1.807	PB	1.4963e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	750.80222	9.12409e-005	0.06850	Propylene
3	0.649	BV	4475.38858	1.02067e-004	0.45679	C3
3	0.687	VB	6697.84171	7.65293e-005	0.51258	NC4
3	0.939	BB	206.17771	8.11249e-005	0.01673	t-2 C4=
3	0.990	BB	145.23926	8.13163e-005	0.01181	i-C4=
3	1.054	BB	279.30612	8.30556e-005	0.02320	1-C4=
3	1.125	PP	128.38203	8.29864e-005	0.01065	c-2-C4=
3	1.381	BB	2108.69080	7.53631e-005	0.15892	i-C5
3	1.504	BB	1584.44403	7.49931e-005	0.11882	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.361	PP	105.00160	7.78266e-005	0.00817	2-meth-2-C4=
3	2.532		-	-	-	1-C5=
3	2.775		-	-	-	c-2-C5=

3	3.654	BB	707.08857	0.00000e+000	0.00000	
4	0.440	BBA	1.2575e+004	2.45182e-005	0.30833	i-C4
4	0.933	BP	1946.79382	0.00000e+000	0.00000	
4	1.009	BP	609.00943	0.00000e+000	0.00000	
4	1.090	BB	940.18802	2.03938e-005	0.01917	n-C6
4	1.310	BP	382.98583	0.00000e+000	0.00000	
4	1.600	PP	213.80978	0.00000e+000	0.00000	
4	2.865	BB	5.4316e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

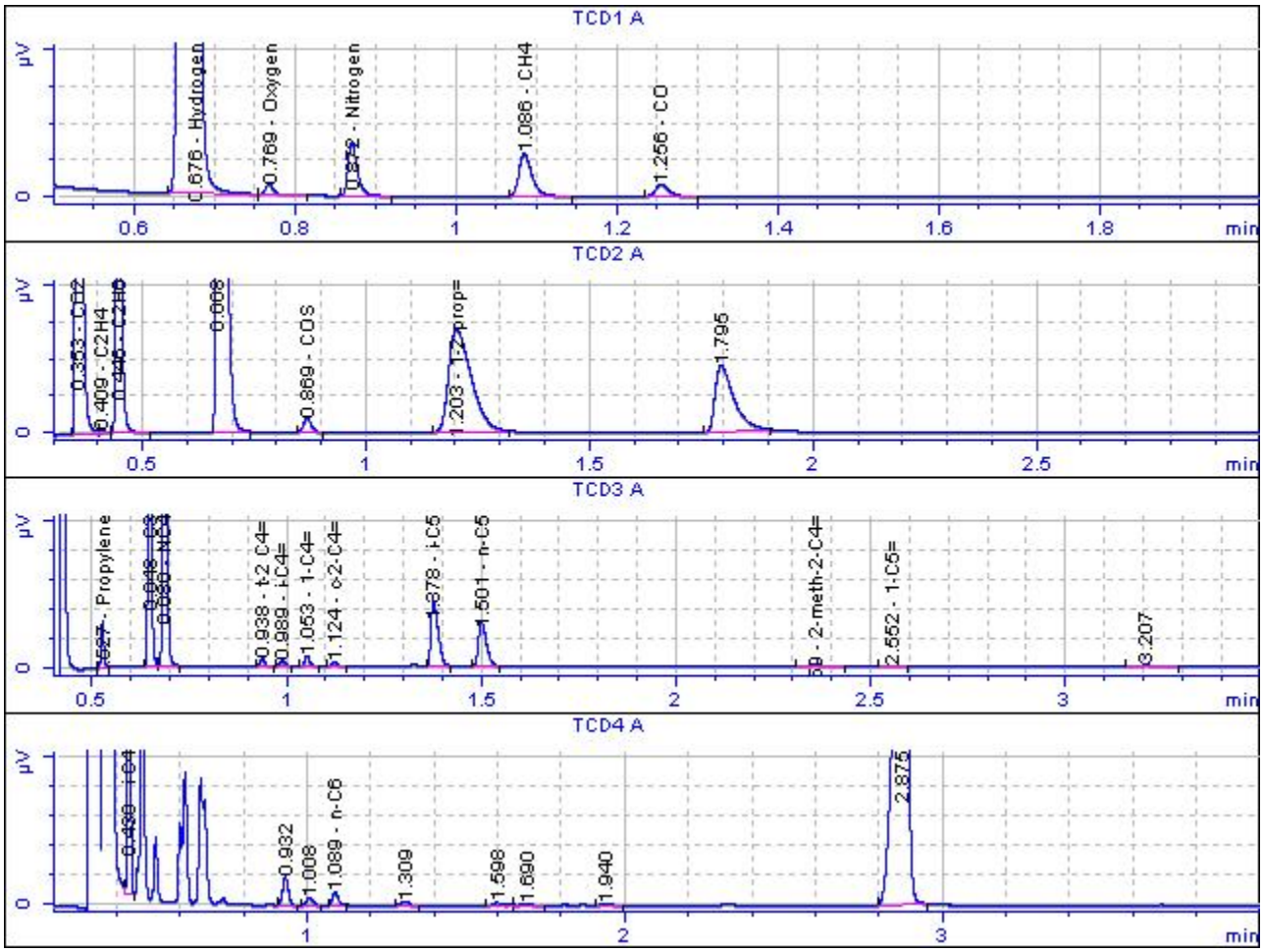
```
Total amount = 54.09308
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

Agilent Cerity QA/QC Report

Sample name:	LGO100HL, 120min
Sample note:	100 H in lagre reactor at time =120
Submission time:	Tuesday, June 02, 2009 2:39:50 PM
Operator:	Aziz
Injection date:	Tuesday, June 02, 2009 2:40:40 PM
GC Description:	Heavy Lab RGA - SN: US10739002
Signal description:	TCD1 A; TCD2 A; TCD3 A; TCD4 A
Method:	Aziz2008
Method last saved:	Tuesday, May 05, 2009 11:40:22 AM



Norm Percent Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Norm %	Name
1	0.676	BV	5.6891e+005	1.05208e-004	63.187508	Hydrogen
1	0.769	VP	1083.84733	1.06315e-003	1.216463	Oxygen
1	0.872	BB	5888.12650	1.25339e-003	7.791118	Nitrogen
1	1.086	BB	6682.99768	5.00940e-004	3.534228	CH4
1	1.256	BB	1913.04766	1.24655e-003	2.517517	CO
2	0.353	PV	2.0328e+005	7.24041e-005	15.538176	CO2
2	0.409	VV	456.13799	7.03854e-005	0.033893	C2H4
2	0.446	VB	3.7821e+004	6.57906e-005	2.626853	C2H6
2	0.548		-	-	-	C2H2
2	0.668	BB	1.3469e+005	0.00000e+000	0.000000	
2	0.698		-	-	-	H2S
2	0.869	BB	2343.98624	6.12584e-005	0.151586	COS
2	1.203	PB	4.9836e+004	1.85836e-005	0.977720	1-2 prop=
2	1.795	PB	2.6795e+004	0.00000e+000	0.000000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	784.46615	9.12409e-005	0.075562	Propylene
3	0.648	BV	6206.81177	1.02067e-004	0.668791	C3
3	0.686	VB	9341.70126	7.65293e-005	0.754730	NC4
3	0.938	PB	247.64093	8.11249e-005	0.021209	t-2 C4=
3	0.989	BB	179.89215	8.13163e-005	0.015443	i-C4=
3	1.053	BB	326.63973	8.30556e-005	0.028640	1-C4=
3	1.124	BP	154.94763	8.29864e-005	0.013575	c-2-C4=
3	1.378	BB	2929.27991	7.53631e-005	0.233054	i-C5
3	1.501	BB	2197.40145	7.49931e-005	0.173968	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.359	PP	138.18484	7.78266e-005	0.011353	2-meth-2-C4=
3	2.552	BP	62.08531	7.76562e-005	0.005090	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.207	PB	174.65936	0.00000e+000	0.000000	
3	3.645	BB	1035.48240	0.00000e+000	0.000000	

4	0.439	BBA	1.5382e+004	2.45182e-005	0.398153	i-C4
4	0.932	BP	2367.89865	0.00000e+000	0.000000	
4	1.008	BP	747.23619	0.00000e+000	0.000000	
4	1.089	BB	1178.40649	2.03938e-005	0.025371	n-C6
4	1.309	BP	477.70926	0.00000e+000	0.000000	
4	1.598	PB	421.65783	0.00000e+000	0.000000	
4	1.690	BP	346.32178	0.00000e+000	0.000000	
4	1.940	PB	316.18277	0.00000e+000	0.000000	
4	2.875	BB	9.5720e+004	0.00000e+000	0.000000	
4	3.726		-	-	-	n-C8

Total norm percent = 100.00000

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log:

ESTD Report

Calibration last saved:	Sunday, November 09, 2008 2:59:17 PM
Multiplier:	1.0000
Dilution:	1.0000
Sample amount:	0.0000 mole%
Sample type:	Sample
Sampling source:	Inlet

Signal	Retention Time [min]	Type	Area [µV*s]	Amt/Area	Amount [mole%]	Name
1	0.676	BV	5.6891e+005	1.05208e-004	59.85404	Hydrogen
1	0.769	VP	1083.84733	1.06315e-003	1.15229	Oxygen
1	0.872	BB	5888.12650	1.25339e-003	7.38010	Nitrogen
1	1.086	BB	6682.99768	5.00940e-004	3.34778	CH4
1	1.256	BB	1913.04766	1.24655e-003	2.38470	CO
2	0.353	PV	2.0328e+005	7.24041e-005	14.71846	CO2
2	0.409	VV	456.13799	7.03854e-005	0.03211	C2H4
2	0.446	VB	3.7821e+004	6.57906e-005	2.48827	C2H6
2	0.548		-	-	-	C2H2
2	0.668	BB	1.3469e+005	0.00000e+000	0.00000	
2	0.698		-	-	-	H2S
2	0.869	BB	2343.98624	6.12584e-005	0.14359	COS
2	1.203	PB	4.9836e+004	1.85836e-005	0.92614	1-2 prop=
2	1.795	PB	2.6795e+004	0.00000e+000	0.00000	
2	1.895		-	-	-	Water
2	2.064		-	-	-	MetyAcetylene
3	0.527	BB	784.46615	9.12409e-005	0.07158	Propylene
3	0.648	BV	6206.81177	1.02067e-004	0.63351	C3
3	0.686	VB	9341.70126	7.65293e-005	0.71491	NC4
3	0.938	PB	247.64093	8.11249e-005	0.02009	t-2 C4=
3	0.989	BB	179.89215	8.13163e-005	0.01463	i-C4=
3	1.053	BB	326.63973	8.30556e-005	0.02713	1-C4=
3	1.124	BP	154.94763	8.29864e-005	0.01286	c-2-C4=
3	1.378	BB	2929.27991	7.53631e-005	0.22076	i-C5
3	1.501	BB	2197.40145	7.49931e-005	0.16479	n-C5
3	1.684		-	-	-	1-3 butadiene
3	2.203		-	-	-	t-2-C5=
3	2.359	PP	138.18484	7.78266e-005	0.01075	2-meth-2-C4=
3	2.552	BP	62.08531	7.76562e-005	0.00482	1-C5=
3	2.775		-	-	-	c-2-C5=
3	3.207	PB	174.65936	0.00000e+000	0.00000	
3	3.645	BB	1035.48240	0.00000e+000	0.00000	

4	0.439	BBA	1.5382e+004	2.45182e-005	0.37715	i-C4
4	0.932	BP	2367.89865	0.00000e+000	0.00000	
4	1.008	BP	747.23619	0.00000e+000	0.00000	
4	1.089	BB	1178.40649	2.03938e-005	0.02403	n-C6
4	1.309	BP	477.70926	0.00000e+000	0.00000	
4	1.598	PB	421.65783	0.00000e+000	0.00000	
4	1.690	BP	346.32178	0.00000e+000	0.00000	
4	1.940	PB	316.18277	0.00000e+000	0.00000	
4	2.875	BB	9.5720e+004	0.00000e+000	0.00000	
4	3.726		-	-	-	n-C8

```
Total amount = 94.72449
```

Report summary:
Warning(s): Calibrated compound(s) not found
Warning(s): Sample amount is zero. Absolute amounts calculated

Instrument run log: